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JOURNAL of PALEONTOLOGY

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ORDOVICIAN CEPHALOPODS FROM THE BLACK HILLS, SOUTH DAKOTA

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ABSTRACT

For the first time representatives of the following cephalopod genera are described from the dolomite member of the Whitewood formation: *Endoceras, Cyclendoceras, Ephippiorthoceras, Spyroceras, Geisonocerina, Lambeoceras, Wilsonoceras, Diestoceras, Westonoceras, Cyrtogomphoceras,* and *Winnipegoceras.* Also there are included descriptions of one species of *Endoceras* and one of *Tripteroceras* from the underlying siltstone portion of the Whitewood. It is concluded that the dolomite member of the Whitewood is to be correlated with the basal or Lander sandstone member of the Bighorn formation of western Wyoming and that the cephalopods it contains are part of an Arctic fauna that is widespread in the Upper Ordovician beds of North America. In an appendix there is described a representative of the unique genus *Winnipegoceras* from the Matapedia series of Quebec.

Although it has been recognized for a long time that the Ordovician Whitewood formation of the Black Hills is the approximate stratigraphic equivalent of the Bighorn formation of the northern Rocky Mountains, the prolific cephalopod fauna of the lower Bighorn has so far not been reported from the Whitewood. However, as early as 1901 Jaggar (8) noted the occurrence of *Endoceras* in the early Paleozoic strata of the Black Hills, and later Walcott (1, 2) identified *Endoceras annulatum* from the same beds.

These casual references constitute all the information that is available in regard to the Whitewood cephalopods, and not a single Ordovician cephalopod has been described from the Black Hills. However, the paleontological collections of the State University of Iowa and those of the Yale Peabody Museum contained a few specimens, and during field work in the summer of 1934 the junior author of the present report obtained a considerable variety of Whitewood cephalopods. His success stimulated us, and the following summer we visited the Black Hills again and collected additional material.

Part of our field expenses were paid from the graduate research funds of the State University of Iowa. Professor C. O. Dunbar kindly loaned us specimens from the collections of Yale University. Also Mr. Frederick O. Thompson, of Des Moines, Iowa, generously contributed the funds which made possible the completion of this study. For all this assistance we acknowledge our indebtedness.

In the northern part of the Black Hills, from which all our specimens came, the Ordovician is represented by some 60 feet of buff dolomite underlain by about the same thickness of sandy and shaly beds (7). Most of the cephalopods we obtained came from the midportion of the dolomite, but we found a few specimens in the underlying clastics. In

the dolomite the cephalopods are limited largely to a zone some 6 or 8 feet thick, where they are associated with *Receptaculites*, *Streptelasma*, *Halysites*, *Hormotoma*, *Maclurina*, and others.

In the collections from the Whitewood formation that we are studying are representatives of the following cephalopod genera: *Endoceras*, *Cyclendoceras*, *Ephippiorthoceras*, *Spyroceras*, *Geisonocerina*, *Tripteroceras*, *Lambeoceras*, *Wilsonoceras*, *Diestoceras*, *Westonoceras*, *Cyrtogomphoceras*, and *Winnipegoceras*. The genus *Endoceras* is world-wide in its distribution, and it has a considerable stratigraphic range within the Ordovician system. Therefore the mere occurrence of this genus within the Whitewood formation has little significance. However, certain of the endoceratoids from the dolomite member of the Whitewood formation are specifically identifiable, and they are referable to *E. fulgur* (Billings) and *E. paliforme* Miller. The first of these two species was originally described from the English Head formation of Anticosti Island, and it has since been found in the Shamattawa limestone of Manitoba and the Lander sandstone member of the Bighorn formation of western Wyoming. *E. paliforme* also occurs in the Lander sandstone. The single representative of *Endoceras* known from the siltstone member of the Whitewood may likewise be referable to *E. fulgur*—the siltstone member of the Whitewood underlies the dolomite member of that formation and is more or less gradational into it.

Cyclendoceras, like *Endoceras*, is abundant in the dolomite member of the Whitewood formation, and it also is widespread geographically, occurring in North America, Europe, and Asia. However, stratigraphically it appears to be limited to the Middle and Upper Ordovician. All our specimens can be referred to *C. abundum* Miller and probably *C. popoagiense* Miller, both of which were described originally from the Lander sandstone member of the Bighorn formation in the Wind River Mountains of western Wyoming.

Representatives of the genus *Ephippiorthoceras* have been found at many localities in North America where they occur in both the Middle and Upper Ordovician as well as in the Silurian, one of the oldest known species having come from the Trenton at Middleville, New York. In Greenland and Norway this genus occurs in the Upper Ordovician. The single specimen known from the Whitewood represents a new species, but it is closely related to *E. dowlingi* Foerste and Savage of the Shamattawa limestone of the Hudson Bay region and possibly of the lower part of the Bighorn formation in the Big Horn Mountains of north-central Wyoming.

The genus *Spyroceras* is known to range from the Ordovician to the Devonian. It is abundant and widespread in North America and occurs also in Europe and Asia. Only one specimen was obtained from the Whitewood formation; it is referable to *S. olorus* (Hall) which was originally described from the Middle

Ordovician (Trenton) of New York but has since been found in the Lander sandstone of western Wyoming. Several groups of species can be recognized within the genus *Spyroceras* (4), but the one to which *S. olorus* belongs has a considerable range within the Ordovician and Silurian.

Recently Foerste (5) established the genus *Geisonocerina* and designated as its genotype *Orthoceras wauwatosense* Whitfield of the Middle Silurian of Wisconsin. Congeneric forms have been described from many horizons and localities in the Ordovician and Silurian of North America. We obtained one specimen from the dolomite member of the Whitewood formation that appears to represent this genus; however, as the surface markings of its conch were not preserved we are uncertain in regard to its affinities, and therefore it is not very significant.

Of the two cephalopod species known from the lower nondolomitic parts of the Whitewood formation, one is referable to *Tripteroceras*. We have three representatives of this form, but they are rather incomplete; hence we cannot determine their specific affinities. As the genus *Tripteroceras* is known to occur in both the Middle and Upper Ordovician of North America, the presence of this genus in the Whitewood is of no great significance. Our specimens probably represent an unnamed species, but they resemble both *T. hastatum* (Billings) of the Middle Ordovician of Pauquettes Rapids, near Ottawa, Ontario, and *T. xiphias* (Billings) of the Vauréal formation of Anticosti Island.

The peculiar flattened nautiloids for which Foerste has proposed the generic name *Lambeoceras* are widespread in the Ordovician strata of North America, but none of them has been found below the Stewartville formation of the upper Mississippi Valley. In Indiana representatives of this genus occur in the Whitewater member of the Richmond, in Wyoming in the Bighorn formation, in Manitoba in the Red River formation, in Baffin Island in strata equivalent to the Red River formation, and in Greenland in the Cape Calhoun beds. We have only one poorly preserved and incomplete specimen from the dolomite member of the Whitewood formation that is referable to this genus, but nevertheless it may well be one of the most significant fossils in our collections.

The genus *Wilsonoceras* is relatively uncommon, and previously representatives of it have been described from only the Red River and Stony Mountain formations of Manitoba and the basal sandstone member of the Bighorn formation in Wyoming and Idaho. The single specimen of this genus that we collected from the dolomite member of the Whitewhood formation is conspecific with a form described from the Lander sandstone member of the Bighorn formation in the Wind River Mountains of Wyoming.

Diestoceras is an almost ubiquitous genus, and representatives of it have been found in the Mohawkian beds of Wisconsin, Michigan, and Ontario;

the Maquoketa formation of Minnesota; the Richmond of Ohio; the Fremont limestone of Colorado; the Bighorn formation of Wyoming; the Red River and Shamattawa limestones of Manitoba; the English Head, Vauréal, and Ellis Bay formations of Anticosti Island; the Frobisher Bay beds of Baffin Island; the Cape Calhoun beds of Greenland; the Upper Ordovician beds near Oslo, Norway (11); and the Lyckholm beds of Estonia (12). We have only one representative of *Diestoceras* from the dolomite member of the Whitewood. This specimen is poorly preserved, but it appears to belong in *D. magister*, a species recently described by Foerste from the Lander sandstone member of the Bighorn formation in the Wind River Mountains of Wyoming.

Foerste's genus *Westonoceras* is known to occur in the Trenton beds of Michigan and Minnesota; the Stewartville formation of Minnesota, Iowa, and Missouri; the Eden of Ohio; the Viola limestone of Oklahoma; the Red River and Shamattawa formations of Manitoba and equivalent beds in southwestern Baffin Island and Akpatok Island; the Cape Calhoun beds of Greenland; and the Upper Ordovician beds near Oslo, Norway. We have four specimens that belong in this genus, but unfortunately all of them are so poorly preserved or incomplete that their specific affinities cannot be determined.

Our collections from the dolomite member of the Whitewood contain representatives of two new species of the unique genus *Cyrtogomphoceras*. This genus has been previously known from only the Red River formation of Manitoba and equivalent beds in southwestern Baffin Island, the Lander sandstone member of the Bighorn formation of western Wyoming, the Fremont formation of Colorado, and the Cape Calhoun beds of Greenland. One of our species, which we are naming *C. foerstei*, is closely related to *C. popoagiense* Foerste of the Lander sandstone, and the other, *C. thompsoni*, resembles *C. whiteavesi* (Miller) of the Red River formation and *C. baffinense* Foerste of Baffin Island.

Of all the cephalopod genera represented in our collections from the Whitewood, *Winnipegoceras* is perhaps the rarest. Representatives of it have been described previously from only the Red River formation of Manitoba, the Lander sandstone of western Wyoming, the Gastropod limestone of the Oslo region (Norway), and possibly the Lyckholm beds of Estonia. In addition, we are describing below a representative of this genus from the Matapedia series of Quebec. Our Whitewood specimen appears to represent a new species, but unfortunately it is so incomplete that we cannot be certain of its generic reference.

From the data presented in the preceding paragraphs it seems clear that the cephalopods of the dolomite member of the Whitewood formation are very closely related to those known from the basal or Lander sandstone member of the Bighorn formation in the Wind River Moun-

tains of western Wyoming (5, 10). They undoubtedly belong to a widely distributed Upper Ordovician Arctic fauna that is known from various localities in western United States, central Canada (3, 6), and Arctic America (13). Some of the other elements of this fauna are even more widespread than the cephalopods. It appears that in Upper Ordovician times, a shallow sea, bringing with it a characteristic fauna, spread southward from the Arctic Ocean over the northern half of Alaska and most of Canada. This sea narrowed to the south, but it extended entirely across west-central United States and into the northern part of Mexico. Several cephalopods have been described from the Fremont limestone, the equivalent of the Whitewood and Bighorn formations, in central Colorado, but south of Colorado cephalopods seem to have been relatively uncommon. Also there is a notable dearth of cephalopods in the collections of Upper Ordovician fossils that have been described from various localities in the northern half of Alaska; therefore correlations have to be based mainly on other groups of invertebrates. In the central and northeastern parts of the sea, however, cephalopods must have abounded, for their remains are very abundant in the Bighorn formation of Wyoming; the Red River and Shamattawa formations of Manitoba; the English Head, Vauréal, and Ellis Bay formations of Anticosti Island; and the Cape Calhoun series of northern Greenland, and strata of equivalent age in Baffin Island. Also a few related cephalopods have been described from the Beaverfoot formation, the equivalent of the Whitewood in southern British Columbia, and a few were collected from the Ordovician of the Great Slave Lake region. We are not entirely certain in regard to the relationship between the faunas of the Whitewood and the Stewartville formation of the upper Mississippi Valley (9). However, Dr. G. Marshall Kay has recently made a large collection of Stewartville cephalopods and loaned it to us for study; it contains many elements in common with the Whitewood, and it seems probable that these two formations are not greatly different in age. A detailed study of the Stewartville cephalopods is to be undertaken in the near future.

Every genus of cephalopods known to be represented in the Whitewood dolomite of the Black Hills occurs also in the Lander sandstone member of the Bighorn formation of western Wyoming, and in most genera specific identities or similarities can be pointed out. The associated fossils at these two localities, particularly the gastropods and corals, are also rather similar, and it seems reasonably certain that the containing beds in both areas are of essentially the same age. It should be pointed out in this connection that in the cephalopod faunas of both the Lander sandstone and the dolomite member of the Whitewood, large straight cephalopods representing the genera *Endoceras* and *Cyclendoceras* are by far the most abundant

forms, and most of the representatives of *Cyclendoceras* belong in the group of *C. abundum*. In the lower part of the Bighorn formation of the northern Big Horn Mountains and in the Red River and Shamattawa limestones of Manitoba and equivalent beds to the north, the relative abundance of the various cephalopod genera is notably different. Presumably this difference indicates that the Whitewood formation and the Lander sandstone were deposited under relatively near-shore conditions, whereas the typical Bighorn, the Red River, and the Shamattawa, were deposited farther from shore. This concept seems to be substantiated by the known distribution of the Ordovician beds in which this fauna has been found.

So few cephalopods are known from the lower or clastic parts of the Whitewood formation that we are not able to add appreciably to the existing knowledge of the age of these beds. Recently, in connection with E. J. Barragy (7), we illustrated part of the fauna of the lower Whitewood and discussed the stratigraphic significance of the contained fossils.

SYSTEMATIC DESCRIPTIONS

ENDOCERAS FULGUR (Billings)
Plate 66, figure 3

Orthoceras propinquum BILLINGS, *1857*, Canada Geol. Survey, Rept. Progress for 1853–54–55–56, p. 320 [not *O. propinquum* Eichwald, *1857?*].

Orthoceras fulgur BILLINGS, *1866*, Canada Geol. Survey, Cat. Sil. Foss. Island Anticosti, p. 22.

Actinoceras fulgur BASSLER, *1915*, U. S. Nat. Mus., Bull. 92, vol. 1, p. 12.

Actinoceras fulgur NICOLAS, *1925*, Canada Geol. Survey, Index to Pal., p. 4.

Endoceras fulgur FOERSTE and SAVAGE, *1927*, Denison Univ., Sci. Lab., Bull., vol. 22, pp. 26–27, pl. 2, fig. 1.

Endoceras fulgur FOERSTE, *1928*, Canada Geol. Survey, Mem. 154, pp. 257–258.

Endoceras fulgur FOERSTE, *1928*, Roy. Soc. Canada, Trans., 3d ser., vol. 22, pt. 2, sec. 4, p. 224, pl. 2, fig. 2; pl. 7, fig. 1; pl. 11, fig. 4.

Endoceras fulgur MILLER, *1932*, Connecticut Acad. Arts and Sci., Trans., vol. 31, pp. 219–221, pl. 1, fig. 5.

Our collections from the Black Hills contain one specimen that is referable to this species. It is an internal mold about 23 cm. long, and it represents parts of 44 camerae of the phragmacone. The conch, which is expanded orad very gradually, appears to be broadly elliptical in cross section, but its exact shape cannot be determined with certainty. There are about 16 camerae in a length equal to the width of the specimen, but, as in the holotype of this species, some of the adoral camerae are slightly longer than certain of the camerae near the mid-length of the specimen. The internal

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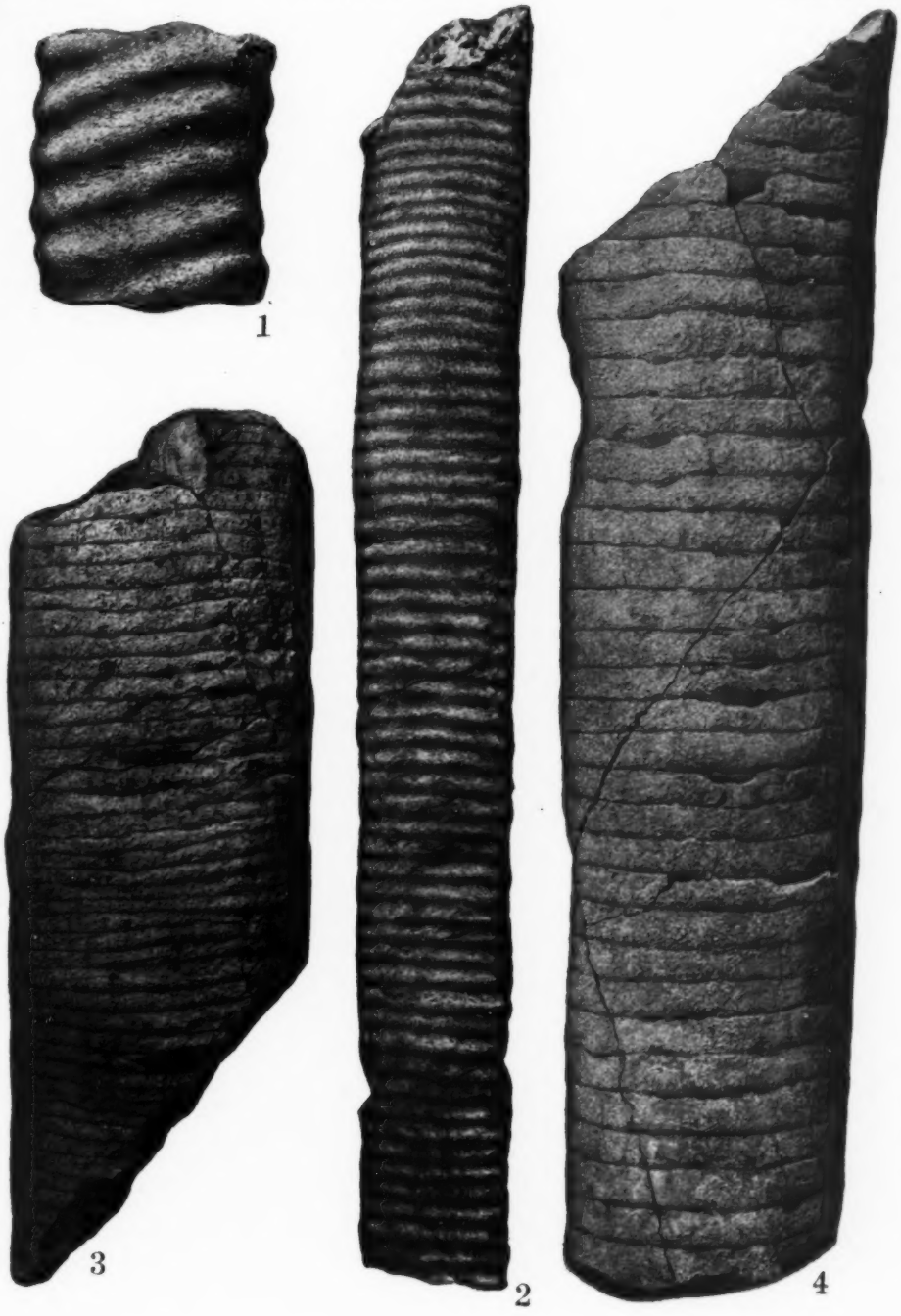
EXPLANATION OF PLATE 66

Fig. *1*—*Cyclendoceras popoagiense* Miller? An internal mold of part of the living chamber, ×½; from dolomite member of Whitewood formation, in canyon of Bear Butte Creek, about 1 mile east of Galena, S. Dak. (p. 543)

2—*Cyclendoceras abundum* Miller. An internal mold of part of the phragmacone, slightly more than ×⅓; from dolomite member of Whitewood formation, on east side of Whitewood Canyon, 1½ miles northeast of Deadwood, S. Dak. (p. 542)

3—*Endoceras fulgur* (Billings). An internal mold of part of the phragmacone, ×½; from midportion of dolomite member of Whitewood formation, on east side of Whitewood Canyon, just northeast of Deadwood, S. Dak. (p. 540)

4—*Endoceras paliforme* Miller. An internal mold of part of the phragmacone, ×⅔; from the same horizon and locality as *3*. (p. 541)



Miller and Furnish, Ordovician Cephalopods

1

2

3

Miller and Furnish, Ordovician Cephalopods

mold is smooth, and no trace of surface ornamentation is discernible on it. The siphuncle is unfortunately not preserved.

Remarks.—As the siphuncle is not preserved in either the holotype of *Endoceras fulgur* or in the specimen under consideration, the identification of our specimen is somewhat uncertain. Nevertheless, all of its characters that can be determined are so strikingly similar to those of the holotype that we feel little hesitation about regarding the two as conspecific. The short camerae and the very gradually expanding conch seem to be two of the most diagnostic features of this species.

Occurrence.—Mid-portion of dolomite member of Whitewood formation, on east side of Whitewood Canyon, just northeast of Deadwood, South Dakota. The holotype of this species came from the English Head formation of Anticosti Island, and conspecific specimens have been described from the Shamattawa limestone of Manitoba and the Lander sandstone member of the Bighorn formation of Wyoming.

Figured specimen.—State Univ. of Iowa, 1216.

ENDOCERAS cf. E. FULGUR (Billings)

The siltstone member of the Whitewood formation has yielded one large fragmentary cephalopod that appears to be closely related to *E. fulgur* but is so incomplete that its specific affinities cannot be determined with certainty. This specimen, an internal mold, is about 24 cm. long, and in its present crushed state it attains a maximum width of about 14½ cm. It represents parts of 25 camerae of the phragmacone and the adapical portion of the living chamber. At least the internal mold of the conch is smooth and devoid of ornamentation. The camerae are short and apparently there are some 16 of them in a length equal to the width of the conch. No trace of the siphuncle is discernible on the specimen.

Occurrence.—Siltstone member of Whitewood formation, near Deadwood, South Dakota, in a road cut on the east side of Whitewood Canyon, about 200 yards east of the intersection of South Dakota State Highway 24 and the Chicago & Northwestern Railway.

Repository.—State Univ. of Iowa, 1217.

ENDOCERAS PALIFORME Miller

Plate 66, figure 4

Endoceras paliforme MILLER, *1932*, Connecticut Acad. Arts and Sci., Trans., vol. 31, pp. 228–229, pl. 4, fig. 2; pl. 12, fig. 5.

We obtained several specimens from the dolomite member of the Whitewood formation that seem to be referable to this species. The most nearly complete of these is represented by figure 4 on plate 66. It is broadly elliptical in cross section but appears to be somewhat crushed. It is gradually expanded orad, and though it is about 43 cm. long its adoral diameter is only about 15 cm. more than its adapical diameter. There is no trace of surface ornamentation on this specimen, an internal mold, and unfortunately its siphuncle is not preserved. The sutures are directly transverse, and the camerae are about one-eighth as long as wide.

Our collections contain three additional specimens that we are referring to this species. All are fragmentary internal molds of parts of phragmacones. Two are considerably larger than the figured specimen and attain a maximum diameter of as much as 16 cm. Their sutures are directly transverse, and their camerae

EXPLANATION OF PLATE 67

FIGS. *1, 2*—*Ephippiorthoceras whitewoodense* Miller and Furnish, n. sp. Ventral and lateral views of holotype, ×1; from dolomite member of Whitewood formation, near Deadwood, S. Dak. (p. 543)

FIG. *3*—*Wilsonoceras neglectum* Miller and Furnish, n. sp. Lateral view of holotype, ×½; from dolomite member of Whitewood formation, just northeast of Deadwood, S. Dak. (p. 546)

are about one-ninth as long as wide. In these two large specimens the siphuncle is close to the margin of the conch, and its diameter is about two-fifths that of the conch. The segments of the siphuncle are slightly but distinctly concave exteriorly. The surface of the internal mold at least is smooth and apparently devoid of markings other than the sutures.

Occurrence.—Midportion of dolomite member of Whitewood formation, on east side of Whitewood Canyon, just northeast of Deadwood, South Dakota. One of the large specimens that we are doubtfully referring to this species came from the same general horizon along Bear Butte Creek, about 1 mile east of Galena, South Dakota; the other two specimens that we are doubtfully referring to this species came from the same general horizon and locality as the figured specimen. The holotype and the paratypes of this species came from the Lander sandstone member of the Bighorn formation of Wyoming.

Repository.—State Univ. of Iowa, 1218 (figured specimen), 1219 and 1220 (specimens from vicinity of Deadwood doubtfully referred to this species), and 1221 (specimen from vicinity of Galena doubtfully referred to this species).

ENDOCERAS spp.

In addition to the specimens described above, our collections from the dolomite member of the Whitewood formation contain 11 specimens that represent the genus *Endoceras*. These show a great deal of variation, but most of them are incomplete and poorly preserved. Nevertheless, certain information can be gleaned from them that seems to be worth recording.

The number of camerae in a length equal to the diameter of the conch ranges in these specimens from about three to about six. The largest of the specimens attains a maximum width of only about 10 cm. The smallest is only about 4 cm. in diameter, and it appears to be circular or nearly so in cross section. The diameter of the siphuncle of this small specimen (and of several of the other specimens) is about two-fifths the diameter of the conch. One of the specimens, which is some 7 cm. in diameter, represents a considerable portion (about 12½ cm.) of the living chamber. Long slender endocones are visible in the siphuncles of two of these specimens, but they are not very well preserved.

These specimens represent at least three species.

Occurrence.—Midportion of dolomite member of Whitewood formation, near Deadwood and Galena, South Dakota; and from the same general horizon in the canyon of Two Bit Creek (about midway between Deadwood and Galena) and in Spearfish Canyon (about 10 miles west of Deadwood).

Repository.—State Univ. of Iowa, 1222–1225.

CYCLENDOCERAS ABUNDUM Miller

Plate 66, figure 2

Cyclendoceras abundum MILLER, *1932*, Connecticut Acad. Arts and Sci., Trans., vol. 31, pp. 232–233, pl. 7, figs. 1–3.

As in the Lander sandstone member of the Bighorn formation of Wyoming, this species is the most abundant cephalopod in the Whitewood formation. Our collections contain 34 specimens that we are referring to it, although they show a certain amount of variation, and most of them are rather poorly preserved and incomplete. In addition, the collections of the Peabody Museum, Yale University, contain a conspecific specimen (pl. 66, fig. 2) from the Black Hills that is 49 cm. in length, which we have been permitted to study through the courtesy of Prof. C. O. Dunbar.

Conch depressed dorsoventrally, subelliptical in cross section, very gradually expanded orad, and moderately large—all but one of our specimens are septate throughout and therefore represent only phragmacone, but one of them attains a maximum width of as much as 9.5 cm. Living chamber of a specimen 5 cm. in diameter is at least 16 cm. long.

Surface of internal mold marked by rounded ridgelike annulations, some seven of which occur in a distance equal to the width of the conch. These annulations are essentially transverse to the long axis of the conch, but they are slightly sinuous. They are not quite parallel to the sutures.

Sutures slightly sinuous but in general directly transverse. Camerae moderate in length, and about seven or eight of them occur in a length equal to the width of the conch. Septa rather strongly convex apicad.

Siphuncle subcentral in position but located considerably closer to the ventral than the dorsal side of the conch. Its diameter is equal to about two-fifths that of the conch. The segments of the siphuncle are slightly but distinctly concave exteriorly.

Remarks.—This species can be readily differentiated from *C. popoagiense*, which occurs, by means of its more numerous, less prominent, and less strongly sinuous annulations.

Occurrence.—Abundant in midportion of dolomite member of Whitewood formation near Deadwood, Galena, and Savoy, South Dakota. The figured specimen came from a locality 1½ miles northeast of Deadwood, on the east side of Whitewood Canyon. The syntypes of this species came from the Lander sandstone member of the Bighorn formation of Wyoming.

Repository.—Peabody Museum, Yale Univ., 5985 (figured specimen); and State Univ. of Iowa, 1226–1234.

CYCLENDOCERAS POPOAGIENSE Miller?
Plate 66, figure 1

Cyclendoceras popoagiense MILLER, *1932*, Connecticut Acad. Arts and Sci., Trans., vol. 31, pp. 241–242, pl. 7, fig. 4; pl. 8, fig. 2.

We obtained one specimen from the Whitewood formation that appears to represent this species, but as it is very incomplete and does not reveal the nature of the siphuncle or the sutures we cannot be certain about its specific affinities. This specimen, an internal mold, is about 7.5 cm. long and 6.5 cm. wide and is not appreciably expanded orad. It appears to be almost circular in cross section. No trace of septa or siphuncle is visible, and therefore the specimen presumably represents a portion of the living chamber. Its surface is marked by prominent sinuous annulations, which are rather strongly inclined to the long axis of the conch.

Remarks.—In this form only five annulations occur in a length equal to the width of the conch, whereas in *C. abundum*, which occurs in association with it, there are seven annulations in a corresponding length. Also in the form under consideration the annulations are much more prominent and more strongly sinuous than in *C. abundum.*

Occurrence.—Dolomite member of Whitewood formation, in canyon of Bear Butte Creek, about 1 mile east of Galena, South Dakota. The syntypes of *C. popoagiense* came from the Lander sandstone member of the Bighorn formation of Wyoming.

Figured specimen.—State Univ. of Iowa, 1235.

EPHIPPIORTHOCERAS WHITEWOODENSE
Miller and Furnish, n. sp.
Plate 67, figures 1, 2

This species is based on a single specimen, an internal mold, which is septate throughout and which represents eight (and part of a ninth) camerae of the phragmacone. The conch is subelliptical in cross section, and it appears to be somewhat less highly arched ventrally than dorsally. It is about 75 mm. long and is very gradually expanded orad. At its adapical end its two diameters measure about 31 mm. and 38 mm., whereas at its adoral end these diameters measure 34 mm. and 42 mm., respectively. Surface of internal mold, at least, is smooth, and the holotype is marked by only the sutures.

Septa moderately convex apicad, and the amount of their curvature is about equal to the length of one camera. Sutures in general transverse but sinuous,

forming broad rounded ventral and dorsal lobes and similar but slightly narrower lateral saddles. There are about four and one-half camerae in a length equal to the width of the conch. Siphuncle subcentral in position but located slightly nearer the venter than the dorsum.

Remarks.—This species is closely related to the genotype of *Ephippiorthoceras, E. formosum* (Billings) of the English Head formation of Anticosti Island, but its conch is less rapidly expanded orad than is that of the genotype. Of all the described representatives of *Ephippiorthoceras, E. dowlingi* Foerste and Savage of the Shamattawa limestone of Manitoba and possibly the lower part of the Bighorn formation of Wyoming (Big Horn Mountains) is perhaps closest to our species. However, the camerae of Foerste and Savage's species are distinctly shorter than are those of the South Dakota form; that is, the camerae of *E. dowlingi* are about one-sixth as long as wide whereas those of *E.whitewoodense* are about two-ninths as long as wide. The conchs of most of the known species of *Ephippiorthoceras* are more rapidly expanded orad than is that of the above-described form.

Occurrence.—Dolomite member of Whitewood formation, near Deadwood, S. Dak.

Holotype.—State Univ. of Iowa, 1236.

SPYROCERAS OLORUS (Hall)

Plate 69, figure 4

Orthoceras vertebrale HALL, *1847*, Pal. New York, vol. 1, p. 201, pl. 43, figs. 5a–5c [not *O. vertebrale* Schlotheim, 1820].

Orthoceras vertebralis BILLINGS, *1857*, Canada Geol. Survey, Rept. Progress for 1853–54–55–56, p. 329.

Orthoceras vertebrale ROGERS, *1858*, Geology of Pennsylvania, vol. 2, pt. 2, p. 819, fig. 608.

Orthoceras vertebrale HITCHCOCK, *1861*, Geology of Vermont, vol. 1, p. 298, fig. 208.

Orthoceras olorus HALL, *1877*, American Palaeozoic Fossils [by S. A. Miller], p. 245.

Orthoceras olorus LESLEY, *1889*, Pennsylvania Geol. Survey, Rept. P 4, vol. 2, p. 554, fig.

Cycloceras olorus GRABAU and SHIMER [part], *1910*, North American Index Fossils, vol. 2, p. 57 [not fig. 1257].

Cycloceras olorus BASSLER [part], *1915*, U. S. Nat. Mus., Bull. 92, vol. 1, p. 326.

Spyroceras olorus FOERSTE, *1928*, Denison Univ., Sci. Lab., Bull., vol. 23, pp. 179–180, pl. 40, fig. 9.

Spyroceras olorus MILLER, *1932*, Connecticut Acad. Arts and Sci., Trans., vol. 31, pp. 248–250, pl. 12, fig. 1.

Spyroceras cf. *S. olorus* FOERSTE, *1935*, Denison Univ., Sci. Lab., Bull., vol. 30, p. 25.

The dolomite member of the Whitewood formation has yielded one specimen that seems to be referable to this species. It is a rather poorly preserved internal mold, which is about 77 mm. long and represents 10 camerae of the phragmacone. It does not appear to be appreciably expanded orad, and it is about 30 mm. in diameter.

The surface is marked by 10 prominent rounded transverse annulations, which are distinctly narrower than the rather flat spaces between them and are parallel to the sutures. Also, although the specimen is rather poorly preserved, traces of rather fine longitudinal lirae are readily discernible on it. All of these lirae seem to be of approximately the same size, and they are slightly more than 1 mm. apart.

Camerae moderately long and about five of them occur in a length equal to the diameter of the conch. Sutures simple circles directly transverse to the long axis of conch, and located in the relatively flat spaces between the transverse ribs. A structure which may represent the siphuncle is central or nearly so in position.

Remarks.—The above-described specimen, though rather poorly preserved, seems to be very similar to both the holotype of this species and the conspecific specimen described by Miller from the Lander sandstone of the Wind River Mountains of Wyoming. Also, it resembles *Spyroceras geronticum* Foerste and Savage of the Shamattawa limestone of Manitoba, but its conch is more gradually expanded than is that of the figured type specimens of the Manitoba species.

Occurrence.—Dolomite member of Whitewood formation, in canyon of Two Bit Creek, about 2½ miles southeast of Deadwood, South Dakota. The holotype of this species came from the Trenton limestone at Middleville, New York. Grabau and Shimer state that this species occurs in the Bighorn formation of Wyoming, and Miller has figured and described a representative of it from the Lander sandstone member of that formation. The forms from the Middle Ordovician of Wisconsin and Minnesota that have been referred to this species are now recognized as being distinct from it.

Figured specimen.—State Univ. of Iowa, 1237.

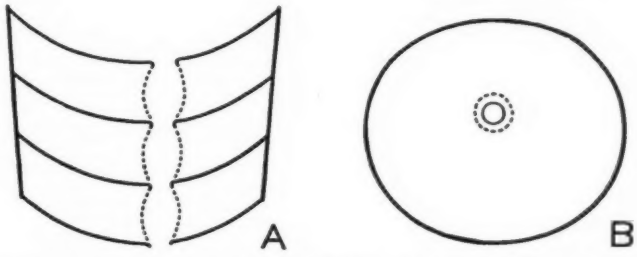


FIG. 1—*Geisonocerina* sp. Diagrammatic longitudinal and cross sections of part of an internal mold from the dolomite member of the Whitewood formation near Deadwood, S. Dak., ×2.

GEISONOCERINA sp.
Text figure 1

There is a single specimen in our collections from the Whitewood formation that apparently may be referred to this genus. It is a moderately well preserved internal mold about 70 mm. long and represents 18 camerae of the phragmacone. Conch is orthoceraconic, rather gradually expanded orad, and subcircular in cross section, being slightly depressed dorsoventrally. At adapical end of specimen conch is about 12 mm. high and 17 mm. wide, and at adoral end of specimen corresponding dimensions are 20 mm. and 27 mm., respectively. The specimen is slightly curved endogastrically, but its curvature is more or less irregular and is probably due to distortion during preservation.

Camerae about one-fourth as long as wide. Sutures straight and directly transverse to long axis of conch.

Siphuncle is subcentral in position but is located distinctly nearer tle venter than the dorsum. It is rather small at its passage through the septa, but it is cyrtochoanitic in structure, and its segments are expanded within the camerae and are fusiform. Where the conch is about 14 mm. high, the segments of the siphuncle attain a maximum diameter within the camerae of about 2½ mm. Septal necks are short and are distinctly recurved. Apparently there are no calcareous deposits within the siphuncle.

Remarks.—The preservation of the above-described specimen is such that fine markings of the test, if originally present, would not have been retained. Therefore, the generic affinities of this specimen cannot be determined with certainty, but all its characters that can be ascertained coincide well with those of typical representatives of *Geisonocerina*.

Occurrence.—Midportion of dolomite member of Whitewood formation, on east side of Whitewood Canyon, just northeast of Deadwood, S. Dak.

Figured specimen.—State Univ. of Iowa, 1247.

TRIPTEROCERAS sp.

Tripteroceras sp. FURNISH, BARRAGY, and MILLER, *1936*, Am. Assoc. Petroleum Geologists, Bull., vol. 20, p. 1340, pl. 1, figs. 22, 23.

From the midportion of the Whitewood formation, about 1 foot below the

base of the dolomite member, we obtained three fragmentary cephalopods, all of which appear to be conspecific. The most nearly complete of these three is about 45 mm. long. It was recently illustrated by Furnish, Barragy, and Miller. Near its adapical end this specimen is about 28 mm. wide and 11 mm. high, whereas near its adoral end these dimensions are about 33 mm. and 16 mm., respectively.

The conch is depressed dorsoventrally and is subtriangular in cross section, being flattened ventrally, broadly rounded dorsally, and narrowly rounded laterally. The rate of divergence of the lateral margins of the conch indicates that the apical angle is slightly more than 10°. At least the internal mold of the conch is smooth. Sutures, septa, and siphuncle are not preserved in our specimens.

Remarks.—The general physiognomy of the specimens under consideration, particularly the shape of the cross section, indicates that they represent the genus *Tripteroceras*. They resemble rather closely both the type species of that genus, *T. hastatum* (Billings) of the Middle Ordovician beds of Pauquettes Rapids near Ottawa, Ontario, and *T. xiphias* (Billings) of the Vauréal formation of Anticosti Island. In cross section they seem to resemble *T. hastatum* rather closely, but their rate of adoral expansion is much more like that of *T. xiphias*.

Occurrence.—All three of our specimens came from the so-called transition beds of the Whitewood formation, about 1 foot below the dolomite member of that formation, in the canyon of Bear Butte Creek about 1 mile east of Galena, S. Dak.

Repository.—State Univ. of Iowa, 1193.

LAMBEOCERAS? sp.

We have one fragmentary specimen from the Whitewood formation that appears to be referable to the genus *Lambeoceras*, but it is so poorly preserved that we cannot be certain of its generic affinities. It represents parts of 10 camerae of the phragmacone, and its width is estimated to be about 55 or 60 mm. The camerae are about one-tenth as long as wide, and the convexity of the septa is equal to two or three times the length of the camerae. Segments of the siphuncle are strongly inflated within the camerae.

Occurrence.—Dolomite member of Whitewood formation, in canyon of Bear Butte Creek about 1 mile east of Galena, S. Dak.

Repository.—State Univ. of Iowa, 1239.

WILSONOCERAS NEGLECTUM Miller and Furnish, n. sp.

Plate 67, figure 3

Wilsonoceras sp. MILLER, *1932*, Connecticut Acad. Arts and Sci., Trans., vol. 31, pp. 263–264, pl. 20, fig. 1.

Conch gyroceraconic, depressed dorsoventrally, subelliptical in cross section and large. The preserved part of the holotype (pl. 67, fig. 3) attained a diameter, measured from the adoral end of the venter across the umbilicus to the opposite side of the specimen, of about 30 cm., and the single paratype (the specimen figured by Miller in 1932) shows that the living chamber is at least two-fifths of a volution in length and that the conch attains a diameter of more than 36 cm. At the adapical end of the holotype the conch is about 75 mm. high and 95 mm. (estimated) wide. During late maturity the relative amount of curvature of the adoral part of the conch decreases progressively, and presumably the adoral part of the living chamber of late mature individuals is not in contact with the preceding volution of the conch.

Surface of internal mold smooth and marked by only the sutures. However, a cast of a small part of the shell is preserved on the dorsolateral wall of the living chamber of the paratype, and it shows that at maturity the shell is about 4 mm. thick and is marked externally by faint transverse ridgelike annulations about 3 mm. apart.

Camerae are about one-sixth as long as high, though the adoral camerae of late mature specimens are of course shorter. Each suture forms a broad

rounded dorsal and ventral lobe and on each of the lateral zones of the conch a broad rounded saddle. The amount of curvature of each suture is equal to about the length of one camera. Siphuncle apparently located dorsad of center of conch, but siphuncle of paratype is not retained and that of holotype is poorly preserved.

Remarks.—This species is perhaps more closely related to *W. squawcreekense* Miller of the Lander sandstone of Wyoming than to the genotype, *W. mccharlesi* (Whiteaves) of the Red River formation of Manitoba, but its conch is relatively higher than that of *W. squawcreekense.*

Occurrence.—Midportion of dolomite member of Whitewood formation, on east side of Whitewood Canyon, just northeast of Deadwood, South Dakota (holotype); and Lander sandstone member of Bighorn formation, near divide between Squaw Creek and Middle Fork of Popo Agie River in the Wind River Mountains, about 10 miles southwest of Lander, Wyo. (paratype).

Types.—State Univ. of Iowa, 1238 (holotype); Univ. of Missouri, 4569 (paratype).

DIESTOCERAS MAGISTER Foerste?

Diestoceras magister FOERSTE, *1935*, Denison Univ., Sci. Lab., Bull., vol. 30, pp. 62–64, pl. 9, fig. 1; pl.. 10, fig. 1.

We have one large specimen that appears to represent this species, but it is so poorly preserved that it cannot be referred to any species with certainty. This specimen represents only one side of the conch, and it appears to be somewhat crushed. It is about 21½ cm. long and attains a maximum diameter of about 17½ cm. The adoral 8½ cm. of the specimen appears to represent living chamber, whereas the adapical 13 cm. is septate and represents 8 camerae of the phragmacone—the adoral 3 camerae are much shorter than the preceding ones. The specimen contracts both orad and apicad, and its maximum diameter is attained slightly orad of the junction of the phragmacone and the living chamber. The adoral end of the living chamber is strongly contracted, and the apertural portions of the conch curve strongly inward. As a result the aperture is only some 10 or 12 cm. in diameter. The phragmacone contracts rather gradually apicad, and at the adapical end of the specimen, which is terminated by a break along a septum, the conch is some 10 cm. in diameter. The specimen is crushed and so poorly preserved that no reliable data can be obtained from it in regard to surface markings of the test, details of the shape of the sutures, or internal structure of the conch.

Remarks.—One of the most distinctive characters of *D. magister* is obviously the great size of its conch.

Occurrence.—Dolomite member of Whitewood formation, just below Roughlock Falls, in the canyon of Little Spearfish Creek west of Savoy, South Dakota. The type specimens of *D. magister* came from the Lander sandstone member of the Bighorn formation in the Wind River Mountains of western Wyoming.

Repository.—State Univ. of Iowa, 1240.

WESTONOCERAS sp.

Plate 69, figure 3

Our collections from the Whitewood formation contain four specimens that probably represent the genus *Westonoceras* but are so incomplete or poorly preserved that their specific affinities cannot be determined. The best preserved of these, an internal mold of six camerae of the phragmacone, is represented by figure 3 on plate 69. It is somewhat distorted, but it is about 36 mm. long and its adapical and adoral diameters measure about 34 mm. and 45 mm., respectively. This specimen, an internal mold, is marked by numerous small longitudinal ribs that occur in many representatives of this genus and related forms as *Diestoceras*, *Landeroceras*, and *Cyrtogomphoceras*. The siphuncle is close to the margin of the conch, and its segments are expanded within the camerae.

The other three specimens from the

Whitewood that we are referring to *Westonoceras* are probably not conspecific with the one figured. All of them are poorly preserved internal molds of breviconic conchs and are larger than the figured specimen.

Occurrence.—Dolomite member of Whitewood formation, just below Roughlock Falls in the canyon of Little Spearfish Creek west of Savoy, S. Dak.

Repository.—State Univ. of Iowa, 1241 (figured specimen) and 1242.

CYRTOGOMPHOCERAS FOERSTEI Miller and Furnish, n. sp.
Plate 68, figures 1, 2

This species is based on a single specimen, a well-preserved internal mold representing essentially all of the living chamber and much of the phragmacone. It is about 14 cm. long, but it is not complete adapically. The conch is breviconic and is slightly curved endogastrically. It is compressed laterally and appears to be more narrowly rounded ventrally than dorsally. At the adapical end of our specimen, which represents a break along a septum, the two diameters of the conch measure about 35 mm. and 25 mm. Throughout most of its length the phragmacone expands orad particularly along the dorsum, but it reaches its maximum size somewhat apicad of the junction of the phragmacone and the living chamber —the maximum dorsoventral diameter measures about 62 mm. and the maximum lateral diameter about 51 mm. Adoral portion of conch contracts, and at adoral end of holotype, which represents essentially the aperture, dorsoventral diameter of conch measures about 38 mm. and lateral diameter about 32 mm. Attention should perhaps be called to the fact that the dorsal outline of the conch is rather evenly convex, whereas the ventral outline is in general concave but is distinctly convex near the junction of the phragmacone and the living chamber. Surface of internal mold appears to be devoid of markings other than the sutures.

Septa are only slightly curved. Camerae moderate in length but in adoral part of phragmacone of mature specimens, such as the one we are studying, they are very short. Sutures straight. In the adapical portion of our specimen the sutures are directly transverse to the long axis of the conch, but adorally they become progressively more and more inclined to that axis so that the adoral sutures slope strongly apicad from the dorsum. At adapical end of holotype center of siphuncle is about 8 mm. from ventral wall of conch. Segments of siphuncle are expanded within the camerae.

Remarks.—This species is named in honor of the late Dr. August F. Foerste, whose studies of nautiloid cephalopods have led to a far better understanding of that group than was ever achieved in the past. Superficially it appears to be closely similar to *C. popoagiense* Foerste of the Lander sandstone of Wyoming. Both of these forms have straight sutures and gradually expanding conchs, but in *C. popoagiense* the conch is depressed dorsoventrally rather than compressed laterally. *C. thompsoni*, which occurs in the Whitewood formation in association with *C. foerstei*, differs in that the lateral part of its adoral sutures are not straight but are strongly convex apicad, and near the junction of the phragmacone and the living chamber the ventral outline of its conch is much less strongly convex than that of *C. foerstei*.

EXPLANATION OF PLATE 68

FIGS. *1, 2*—*Cyrtogomphoceras foerstei* Miller and Furnish, n. sp. Dorsal and lateral views of the holotype, ×⅔; from dolomite member of Whitewood formation, in canyon of Bear Butte Creek, about 1 mile east of Galena, S. Dak. (p. 548)

3—*Cyrtogomphoceras thompsoni* Miller and Furnish, n. sp. Lateral view of the holotype, ×⅔; from the same horizon and locality as the last. (p. 549)

2

3

1

Miller and Furnish, Ordovician Cephalopods

Miller and Furnish, Ordovician Cephalopods

Occurrence.—Dolomite member of Whitewood formation, in canyon of Bear Butte Creek, about 1 mile east of Galena, S. Dak.

Holotype.—State Univ. of Iowa, 1243.

CYRTOGOMPHOCERAS THOMPSONI
Miller and Furnish, n. sp.
Plate 68, figure 3

Conch breviconic, compressed laterally, and moderate in size—the holotype of this species, which is not quite complete adapically, is about 175 mm. long, and the single paratype appears to have been of about the same size. Conch is slightly curved endogastrically. At maturity living chamber is about one-third as long as phragmacone. Phragmacone is expanded orad throughout most of its length, but conch attains its greatest dimensions somewhat apicad of adoral end of phragmacone. At adapical end of holotype, which does not represent adapical end of conch, conch is about 27 mm. high and about 18 mm. (estimated) wide. Maximum height attained by conch of holotype measures about 70 mm. and maximum width about 60 mm. (estimated). Adoral portion of conch contracts, and at adoral end of holotype, which represents aperture, conch is about 47 mm. high and 31 mm. wide. As in *C. foerstei*, described above, the dorsal outline of the conch is evenly convex but the ventral outline, though in general concave, is very slightly convex near the junction of the phragmacone and the living chamber. Surface of internal mold, at least, smooth, and on the holotype there is no indication of any markings other than the sutures.

Camerae moderate in length, but near adoral end of phragmacone of large mature specimens, like the holotype, camerae are very short. On adapical portion of holotype sutures are straight and are directly transverse to long axis of conch; adorally, however, they become progressively more and more inclined to that axis, sloping apicad from the dorsum, and at the same time the lateral part of the sutures become progressively more and more strongly concave orad.

At adapical end of holotype center of siphuncle is about 5 mm. from venter. Siphuncle is small at its passage through the septa, but its segments are expanded within the camerae so as to appear almost nummuloidal. Near adapical end of paratype, where conch is about 40 mm. high, segments of siphuncle attain a maximum diameter with the camerae of about 13 mm.

Remarks.—This species, which is established for the finest specimen in our collections from the Whitewood formation, is named in honor of Mr. Frederick O. Thompson, of Des Moines, Iowa, through whose generous financial assistance the completion of this study was made possible. The conch of this species is similar to those of *C. whiteavesi*(Miller) of the Red River formation of Manitoba and *C. baffinense* Foerste of equivalent beds in Putnam Highland of western Baffin Island, but it is less rapidly expanded than are the conchs of these two Canadian species. In *C. foerstei*, which occurs in the Whitewood formation in association with *C. thompsoni*, the lateral zones of the adoral sutures are straight, or nearly so, and the ventral convex zone

EXPLANATION OF PLATE 69

FIG. *1*—*Winnipegoceras* aff. *W. laticurvatum* (Whiteaves). An artificial internal mold, ×1; from Matapedia series, 3 miles upstream from Matapedia, Quebec. (p. 551)

2—*Winnipegoceras* sp. Lateral view of an incomplete internal mold, ×1; from dolomite member of Whitewood formation, just northeast of Deadwood, S. Dak. (p. 550)

3—*Westonoceras* sp. An internal mold of part of the phragmacone, ×1; from dolomite member of Whitewood formation, in canyon of Little Spearfish Creek, near Savoy, S. Dak. (p. 547)

4—*Spyroceras olorus* (Hall). An internal mold of part of a phragmacone, ×1; from dolomite member of Whitewood formation, in canyon of Two Bit Creek, about 2½ miles southeast of Deadwood, S. Dak. (p. 544)

of the conch near the junction of the phragmacone and the living chamber is much more prominent than in *C. thompsoni.*

Occurrence.—Dolomite member of Whitewood formation, canyon of Bear Butte Creek about 1 mile east of Galena, S. Dak.

Types.—State Univ. of Iowa, 1244 (holotype) and 1245 (paratype).

WINNIPEGOCERAS sp.
Plate 69, figure 2

We have a single specimen from the Whitewood formation that we are referring to the genus *Winnipegoceras.* It is about 110 mm. long but is not complete adapically or adorally. The adoral nine camerae of the phragmacone and the adapical 40 mm. of the living chamber are represented by this specimen. The conch is curved exogastrically and the ventral outline of the preserved part of it is convex, whereas the dorsal outline is concave. The specimen is crushed and flattened laterally, and the adapical portion of it is more strongly crushed than the adoral portion. Therefore the shape of the cross section of the conch cannot be determined, but probably it was somewhat compressed laterally and was oval in cross section. Surface of specimen marked by only the sutures. These are in general transverse to the long axis of the conch, but each of them forms a broad shallow lobe on the lateral sides of the specimen. A structure that appears to represent the siphuncle is located fairly close to the venter.

Remarks.—This specimen is so incomplete that its generic affinities are somewhat questionable. It does not appear to be particularly close to any of the named species of *Winnipegoceras, W. laticurvatum* (Whiteaves) of the Red River formation of Manitoba and the Lander sandstone of Wyoming, *W. dowlingi* Foerste of the Red River formation of Manitoba, and *W. fragmentaricum* Strand of the Gastropod limestone near Oslo, Norway.

Occurrence.—Midportion of dolomite member of Whitewood formation, east side of Whitewood Canyon, just northeast of Deadwood, S. Dak.

Figured specimen.—State Univ. of Iowa, 1246.

APPENDIX

A *Winnipegoceras* from the Ordovician of the Matapedia Valley, Quebec

During the summer of 1929, G. A. Cooper and G. W. Crickmay collected a single cephalopod from dark-gray calcareous phyllites of the Matapedia series on the east bank of the Restigouche River, 3 miles upstream from Matapedia, Quebec. The specimen was submitted to the late Dr. August F. Foerste, who recognized its affinities with *Winnipegoceras laticurvatum* (Whiteaves), and in 1932 Crickmay listed it as "*Winnepegoceras* sp."

In association with this cephalopod, Crickmay found only *Cyclopyge* aff. *C. kindlei* Cooper and *Cyclospira? canadensis* Cooper. According to Crickmay

> The fossils in themselves are not sufficient for definite correlations with the Ordovician succession in the interior of North America, but there can be little doubt that the beds from which they come are the direct equivalents of the late Ordovician at Percé, the Whitehead formation. The Whitehead formation according to Schuchert and Cooper (1930), is equivalent to the middle and upper

Richmondian but not as late as the Gamachian.

WINNIPEGOCERAS aff. W. LATICURVATUM
(Whiteaves)

Plate 69, figure 1

Winnepegoceras sp. CRICKMAY, *1932*, Am. Jour. Sci., 5th ser., vol. 24, p. 379.

The specimen we are studying is represented by both an internal mold and a reverse of it. Our illustration is based on an artificial internal mold, as the natural one is rather fragmentary. The conch is curved and is cyrtoceraconic. Figure 1 on plate 69 portrays its size, shape, and general physiognomy as clearly as does the specimen. The adoral end of the specimen appears to represent the apertural margin of the conch, but apically and laterally the specimen is incomplete. It has been compressed laterally so that the edges of the septa project as slight ridges, and the shape of the cross section of the conch cannot be determined. The conch appears to have attained its greatest dimensions slightly apicad of the junction of the phragmacone and the living chamber. The sutures are in general transverse to the long axis of the conch, but they form broad shallow rounded lateral lobes. The siphuncle is not retained.

Remarks.—This specimen is so incomplete and poorly preserved that it is difficult to determine with certainty its specific affinities. However, it appears to represent an unnamed species that is related to *W. laticurvatum*, the genotype of *Winnipegoceras*. The curvature and general physiognomy of its conch and its sutures indicate its relationship to that species and at the same time show that it is specifically distinct.

Occurrence.—Dark-gray calcareous phyllites of the Matapedia series, on the east bank of the Restigouche River, 3 miles upstream from Matapedia, Quebec.

Figured specimen.—Peabody Museum, Yale Univ.

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LOWER NEOCOMIAN FOSSILS FROM THE MIQUIHUANA REGION, MEXICO

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ABSTRACT

This paper lists 37 species of invertebrate fossils from Tamaulipas and adjacent Nuevo León, Mexico, of which 7 ammonites, 3 exogyras, and 6 brachiopods are described as new. The ranges of the ammonites indicate a Valanginian age. The beds containing them are probably equivalent to some part of the lower member of the Taraises formation.

Most of the material described in this paper was obtained from the vicinity of Miquihuana in southwestern Tamaulipas, but some came from Rancho San Lazaro, in southern Nuevo León (fig. 1). Burckhardt has discussed the age and stratigraphic relations of the Lower Cretaceous and Jurassic strata in the Miquihuana region and has commented upon the fossils. The present paper describes the Lower Cretaceous fossils, presents some stratigraphic sections, and in general confirms Burckhardt's conclusions (2, pp. 85–90).

During 1925 some geologic studies were made in the Sierra Madre Oriental of Mexico by the East Coast Oil Company, of which C. L. Baker was chief geologist. It was under his direction that the fossils described in this report were collected. The fossils were subsequently turned over to the Transcontinental Petroleum Company, which gave them to the University of Michigan in 1928. Credit for studying and measuring the stratigraphic sections described herein is due C. L Baker, L. G. Putnam, L. C. Reed, and E. R. Silliman. The studies of the lower Neocomian fossils of the Miquihuana region were made in the Horace H. Rackham School of Graduate Studies of the University of Michigan and were suggested by Prof. Lewis B. Kellum.

STRATIGRAPHY

In the vicinity of Miquihuana the Lower Cretaceous section is about 4,200 feet thick. It consists mainly of limestones but near the base contains sandy and shaly beds and locally a basal conglomerate. It is underlain with angular unconformity by red beds about 820 feet thick, which are underlain, also with angular unconformity, by talc schist. Near San Lazaro, about 16 miles northwest of Miquihuana, marine Lower Cretaceous beds rest concordantly on marine Jurassic beds, but the fossils contained in the boundary beds show that the highest Jurassic and the lowest Cretaceous are missing. Unit 3 contains *Idoceras* and is therefore probably of Kimmeridgian age. Overlying unit 4 contains species of *Thurmannites* identical with those in the basal Cretaceous beds at Miquihuana,

which is considered to be of Valanginian age.

Beds similar lithologically and stratigraphically to those near Miquihuana occur in nearby parts of the Sierra Madre Oriental. The probable equivalent of the basal talc schist occurs near Peregrina (15, pp. 7–8) and Catorce (2, pp. 77–78) (see index map). Red beds occur near Peregrina, at Rancho Huizachal, Mezquital, and Catorce (2, pp. 77, 85–89). Upper Jurassic beds of shallow water origin, similar to those near San Lazaro, have been found near Peregrina, Rancho Huizachal, and at Mezquital. At Miquihuana, the Lower Cretaceous sediments rest directly on the red beds. The thick section of Lower Cretaceous limestone near Miquihuana is of considerable interest, as the upper part consists of reef limestone bearing rudistids and miliolids. Muir (15, p. 23) states that the Tamaulipas limestone (deep-water facies) exists in the front ranges of the Sierra Madre Oriental from Monterrey to Victoria. Burckhardt (2, p. 171) has shown the presence of a deep-water facies west of Miquihuana. The presence of the reef facies of the Middle Cretaceous at Miquihuana suggests that a reef facies lying between two bathyal facies may be fairly continuous along the Sierra Madre Oriental from the region of Saltillo southward (2, p. 176).

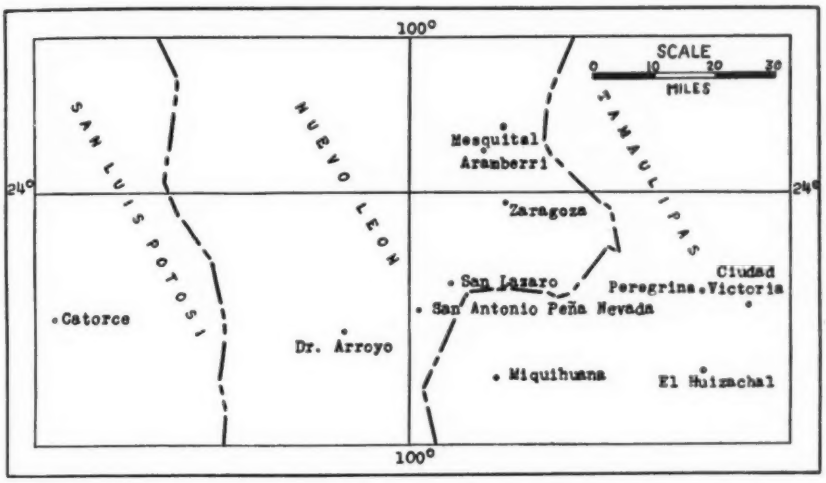


FIG. 1—Index map of parts of Tamaulipas, Nuevo León, and San Luis Potosí, Mexico.

In parts of Coahuila, as at Miquihuana, reefs of Middle Cretaceous age were built in areas that were land masses in late Jurassic and early Cretaceous time (7, p. 1145; 8, pp. 604–605; 11, p. 1036). These relations contrast with those in other areas, as near Mazapil, Zacatecas, where deposition appears to have been continuous from the Jurassic into the Cretaceous and no reefs were formed. Is there possibly some defi-

nite relation between the occurrence of the reef limestones of the Middle Cretaceous and the height of the land at the end of the Jurassic?

The following section was measured by C. L. Baker in January, 1925, about 1 mile east of the center of Miquihuana near the foot of a southward-facing spur that is slightly

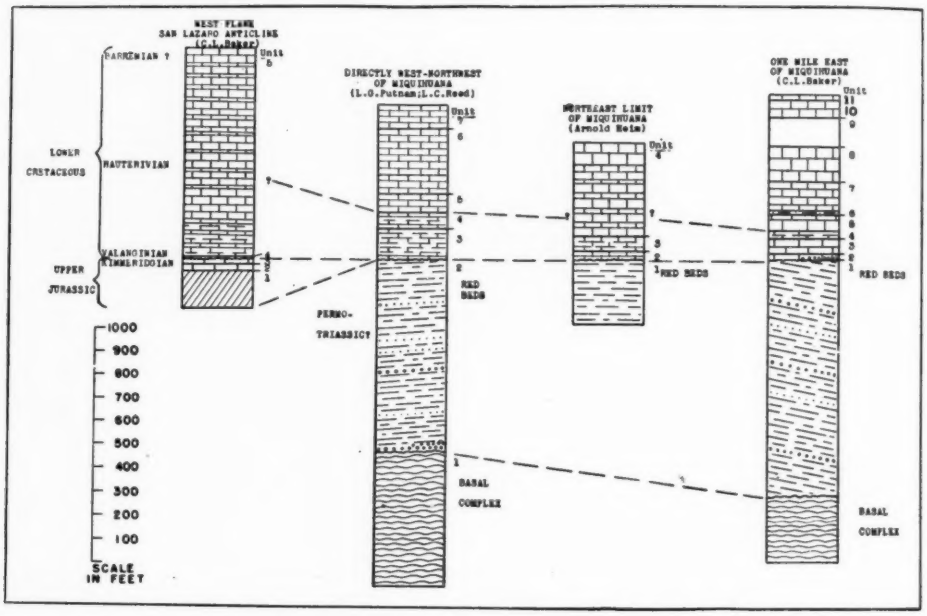


FIG. 2—Stratigraphic sections of the Miquihuana region. (Sections by C. L. Baker, L. G. Putnam, and L. C. Reed not published previously.)

north of the road leading into the city (see fig. 2).

Section 1 mile east of Miquihuana	*Feet*
11. Limestone, crystalline, dark, strong odor, fossiliferous	30
10. Limestone, dense, fossiliferous	75
9. Covered by debris	125
8. Limestone, crystalline, strong odor	150
7. Limestone, dense	125
6. Shale, sandy, contains ammonites	15
5. Limestone, medium- to thick-bedded, with nodules and concretions of rusty chert	68
4. Limestone, argillaceous, light brown, with blocky jointing; includes some marls; weathers pinkish along joints. Some ammonites (collection B.5)	32
3. Limestone, thin- to medium-bedded, phosphatic, dark blue-gray; weathered surfaces appear ashy-gray and marly; numerous brachiopods, pelecypods, and ammonites. Collection B.2 from base; collection B.3 from middle; collection B.4 from upper 10 feet	63+
2. Limestone, dark gray, dense, locally conglomeratic. One thick bed of dark blue-gray crystalline limestone contains corals. Small particles	

of rusty chert. Collection B.1. Overlies red beds with an angular unconformity of 8° to 10°..... 25

1. Red beds. Red shale and some conglomerate beds. Contact with underlying metamorphic rock seen only at faulted exposure. At least..... 1,000

A section measured by Arnold Heim immediately northeast of the reservoir at the northeast limit of Miquihuana has been published by Burckhardt (2, pp. 155, 156), whose description may be translated as follows:

Section near reservoir at Miquihuana

4. Tamaulipas limestone. A large series of thick-bedded limestones.
3. Marly series of the Valanginian..... .....100–150 m. ±
   3b. The same marls with beds of dark limestone, brownish on the surface, which contain oysters and large ammonites.
   3a. 15–20 m. Marls, brownish, finely sandy, with some oysters (*Exogyra couloni* Defrance?). Similar to the "Oehrlimergel" of the Valanginian of the Swiss Alps.
2. Basal limestones. Terminating toward the southwest.....12 m. ±
   2b. 8 m. ± Limestone, massive, crystalline, with reddish streaks. Upper limit invisible.
   2a. 4 m. Limestone, nodular, with brachiopods and small oysters.
1. Red beds, probably Permo-Triassic. Shaly clays, finely sandy, red and green, with some beds of sand. Upper limit distinct but without notable discordance.

C. L. Baker made a fine collection of fossils near the base of the Cretaceous at the reservoir. The large ammonites occur in higher beds than the brachiopods and oysters.

A section on the west flank of the San Lazaro anticline about 0.6 mile (1 k.) south of the pass on the San Lazaro-Zaragosa trail was measured by Mr. Baker and associates in 1925 (fig. 2). From top to bottom the section is as follows:

Section on the San Lazaro Anticline

	Feet
5. Limestone, mostly covered except for lower 165 feet, which consists of interbeds similar to units (3) and (4) and which grades upward into medium-bedded limestone lithologically like unit (4). Ammonites collected from lower 490 feet	885
4. Limestone, fine-grained, blue-gray, faintly laminated, contains ammonites of Valanginian age.....	10 ±
3. Limestone, argillaceous, finely laminated, gray, black, brownish-black and ashy, containing phosphatic concretions. Ammonites of Kimmeridgian age (several species of *Idoceras*).....	23
2. Limestone, fine-grained, phosphatic, dark gray above; becomes nodular, gypsiferous, and light gray below; calcite veined. Baker records "*Terebratula*" and *Alectryonia* at top.....	33
1. Gypsum, white, laminated alabaster.....	165 ±
	1,116

A section on the west bank of Arroyo San Lazaro opposite a spring at the mouth of Cañon Tijera, about a mile north of Rancho San Lazaro, was studied by Baker and associates in 1925. From top to bottom the section is as follows:

Section on Arroyo San Lazaro

9. Limestone, thin- to medium-bedded, laminated, blue-gray, contains chert lenticles and nodules.

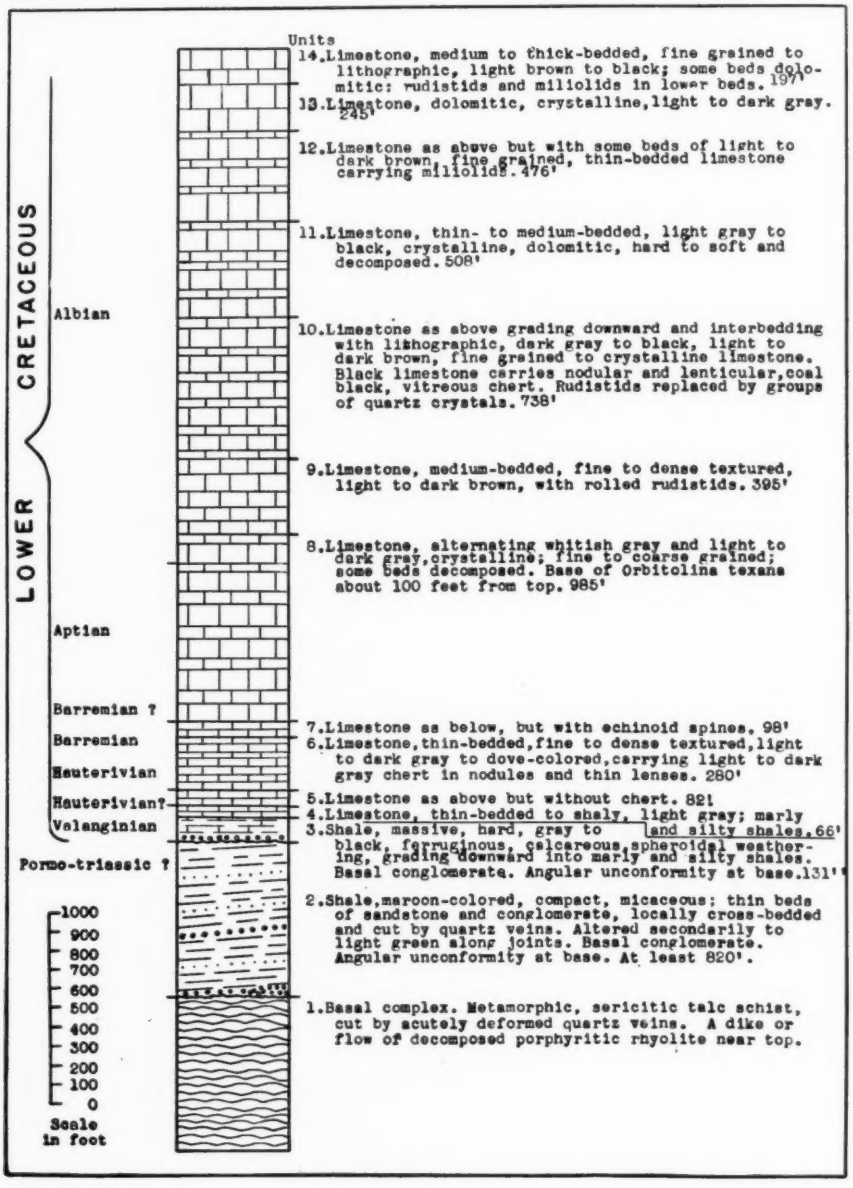

Units
14.Limestone, medium to thick-bedded, fine grained to lithographic, light brown to black; some beds dolomitic: rudistids and miliolids in lower beds. 197'
13.Limestone, dolomitic, crystalline, light to dark gray. 245'
12.Limestone as above but with some beds of light to dark brown, fine grained, thin-bedded limestone carrying miliolids. 476'
11.Limestone, thin- to medium-bedded, light gray to black, crystalline, dolomitic, hard to soft and decomposed. 508'
10.Limestone as above grading downward and interbedding with lithographic, dark gray to black, light to dark brown, fine grained to crystalline limestone. Black limestone carries nodular and lenticular, coal black, vitreous chert. Rudistids replaced by groups of quartz crystals. 738'
9.Limestone, medium-bedded, fine to dense textured, light to dark brown, with rolled rudistids. 395'
8.Limestone, alternating whitish gray and light to dark gray, crystalline; fine to coarse grained; some beds decomposed. Base of Orbitolina texana about 100 feet from top. 985'
7.Limestone as below, but with echinoid spines. 98'
6.Limestone, thin-bedded, fine to dense textured, light to dark gray to dove-colored, carrying light to dark gray chert in nodules and thin lenses. 280'
5.Limestone as above but without chert. 82'
4.Limestone, thin-bedded to shaly, light gray; marly
3.Shale, massive, hard, gray to and silty shales. 66'
black, ferruginous, calcareous, spheroidal weathering, grading downward into marly and silty shales. Basal conglomerate. Angular unconformity at base. 131'
2.Shale, maroon-colored, compact, micaceous; thin beds of sandstone and conglomerate, locally cross-bedded and cut by quartz veins. Altered secondarily to light green along joints. Basal conglomerate. Angular unconformity at base. At least 820'.
1.Basal complex. Metamorphic, sericitic talc schist, cut by acutely deformed quartz veins. A dike or flow of decomposed porphyritic rhyolite near top.
LOWER CRETACEOUS
Albian
Aptian
Barremian ?
Barremian
Hauterivian
Hauterivian?
Valanginian
Permo-triassic ?
1000
900
800
700
600
500
400
300
200
100
0
Scale in feet

FIG. 3—Immediately west-northwest of Miquihuana on west flank of Miquihuana anticline. (Measured by L. G. Putnam and L. C. Reed in 1925.)

8. Limestone, thin-bedded, nodular-veined and fractured, dense, blue-gray; some thin interbedded ashy and shaly marls. Ammonites abundant, especially *Rogersites* and *Thurmannites*.
7. Limestone, medium-bedded, dense, blue-gray.
6. Gypsum, apparently very thick.
5. Limestone, thin- to medium-bedded, dense, blue-gray.
4. Gypsum.
3. Limestone, thin-bedded, blue-gray, interbedded ashy marls with small *Exogyra* and "*Terebratula*"; somewhat phosphatic.
2. Gypsum, thinly laminated.
1. Limestone, thin-bedded, much fractured, blue-gray; maroon and yellowish shales.

FOSSILS AND CORRELATION

The fossils found in the basal Cretaceous beds of the Miquihuana region are shown in the following table. The list includes 6 genera and at least 16 species of ammonites; 8 genera and 12 species of pelecypods; 4 genera and 6 species of brachiopods; and 1 species of worm. There are also a few specimens of bryozoa. The ammonites and some of the pelecypods are preserved as internal molds. The oysters and brachiopods retain much of the calcareous shell, although the outer layers have been partly destroyed. Many of the fossils are distorted, especially the brachiopods collected near the reservoir.

Among the pelecypods only the oysters are well preserved and abundant. *Exogyra reedi* Imlay is somewhat similar to *E. coulonii* Defrance (4, pp. 698–701, pls. 466, 467, figs. 1–3), which is fairly characteristic of the lower Neocomian.

Brachiopods are very abundant. They comprise 12 species distributed among at least 6 genera, but of these only 6 species distributed among 4 genera are sufficiently well preserved to merit description. The generic determinations should be considered only tentative, pending redefinition of the Lower Cretaceous brachiopod genera on the basis of both external and internal structures.

The ammonites assigned to *Thurmannites* belong to a group which Uhlig (18, p. 167; 19, p. 554) placed in *Acanthodiscus* on the basis of the trituberculate sculpture of the later growth stages. Kilian (13), however, has shown that the costate sculpture of the early stages of growth is like that of *Thurmannites* and unlike the trituberculate sculpture of the early stages of *Acanthodiscus* sensu strictu (as typified by *A. radiatus* Bruguière). If it can be shown that the adult forms of the genotype of *Thurmannites* do not become tuberculate, then perhaps the forms that become strongly tuberculate, such as described in this paper, should be placed in a new genus.

The occurrence of the ammonite *Favrella* in Mexico is particularly interesting because it has been recorded before only from Argentina and Patagonia (6, p. 480). *Rogersites* is very abundant in individuals and species. *Valanginites* is represented by several specimens.

Chief reliance for an age determination of the basal Cretaceous beds of the Miquihuana region must be placed on the ammonites. *Rogersites* occurs characteristically in the upper Valanginian (17, pp. 86–87, table 3).

Thurmannites appears to range through most of the lower Neocomian. *Valanginites* is recorded from both the Valanginian and Lower Hauterivian (12, pp. 9, 12). *Favrella* is reported to occur in both the Valanginian and lower Hauterivian (6, p. 483; 20, p. 460).

The ranges of the ammonite genera favor a Valanginian age. Indirectly the absence of certain ammonite genera also indicates the same thing.

Distribution of fossils from basal Cretaceous beds of the Miquihuana region, Tamaulipas and Nuevo León, Mexico

	One mile east of Miquihuana					Reservoir	Directly west-northwest of Miquihuana		Arroyo San Lazaro	West flank of San Lazaro anticline	
Collection	1	2	3	4	5						
Unit of section	2	3	3	3	4		3	4	8	4	5
Rogersites filifer Imlay	—	—	—	—	—	—	—	—	×	—	×
Rogersites aff. *R. filifer* Imlay	—	—	—	—	—	—	—	×	—	—	—
Rogersites bakeri Imlay	—	—	—	—	—	—	—	—	×	—	—
Rogersites prorsiradiatus Imlay	—	—	—	—	—	—	—	—	×	—	—
Rogersites sanlazarensis Imlay	—	—	—	—	—	—	—	—	×	—	—
Rogersites paucicostatus Imlay	—	—	—	—	—	—	—	—	×	—	—
Rogersites tenuicostatus Imlay	—	—	—	—	—	—	—	—	×	—	—
Rogersites? sp.	—	—	—	—	—	×	—	—	—	—	—
Valanginites tijerensis Imlay	—	—	—	—	—	—	—	—	×	—	—
Valanginites sp.	—	—	—	—	—	—	—	—	—	—	×
Bochianites? sp.	—	—	—	—	—	—	—	—	—	—	×
Thurmannites novihispanicus Imlay	—	×	—	—	—	×	—	×	?	—	—
Thurmannites angusticostatus Imlay	—	—	—	—	—	×	—	—	×	—	—
Thurmannites miquihuanensis Imlay	—	—	—	—	×	×	—	—	—	×	—
Thurmannites sp. a	—	—	—	—	×	×	—	—	—	×	—
Thurmannites sp.	—	—	×	×	×	—	—	—	—	—	—
Distoloceras aff. *D. parritense* Imlay	—	—	—	—	—	—	—	—	—	—	×
Favrella sp.	—	—	—	—	—	—	—	—	×	—	—
Trigonarca? sp.	—	—	—	—	—	—	—	—	×	—	—
Exogyra putnami Imlay	—	×	×	×	—	×	×	×	—	—	—
Exogyra reedi Imlay	×	×	×	×	—	×	×	×	—	—	—
Exogyra tamaulipana Imlay	—	×	×	×	—	—	×	—	—	—	—
Exogyra sp.	×	—	—	—	—	—	—	—	—	—	—
Gryphaea sp.	—	—	—	—	—	—	×	—	—	—	—
Cardium sp.	×	—	—	—	—	—	—	—	—	—	—
Lucina sp.	—	×	—	—	—	—	—	—	—	—	—
Cuculaea sp.	—	—	—	—	—	—	×	—	—	—	—
Pecten sp. a	×	×	—	—	—	—	—	—	—	—	—
Pecten sp. b	×	×	×	—	—	—	—	—	—	—	—
Pleuromya sp.	×	×	—	—	—	—	—	—	—	—	—
Vermetus sp.	—	×	×	×	—	—	×	—	—	—	—
Cyclothyris? subtrigonalis Imlay	—	—	—	—	—	×	—	—	—	—	—
"*Rhynchonella*" *miquihuanensis* Imlay	—	—	—	—	—	×	—	—	—	—	—
Antiptychina? mülleriedi Imlay	—	—	—	—	—	×	—	—	—	—	—
Antiptychina? lata Imlay	—	—	—	—	—	×	—	—	—	—	—
"*Terebratula*" *tamaulipana* Imlay	×	×	×	×	—	—	—	—	—	—	—
"*Terebratula*" *sillimani* Imlay	—	×	×	×	—	×	—	—	—	—	—

If beds of Berriasian age were present, the genera *Spiticeras*, *Berriasella*, or *Steueroceras* might be expected, as these occur elsewhere in Mexico, at the base of the Cretaceous section. If beds of Hauterivian age were present, then some of the species should be identical with the species of the upper member of the Taraises formation of the Sierra de Parras section which the writer has shown is almost certainly of lower Hauterivian age (9). But there is not a species in common between the basal Cretaceous of the Miquihuana region and the upper member of the Taraises formation of the Sierra de Parras, although both are richly fossiliferous. *Distoloceras* aff. *D. parritense* Imlay from unit 5 of the section on the west flank of the San Lazaro anticline is closely related to a species from the upper member of the Taraises formation, but its exact position in unit 5 is unknown, and it may very well come from younger beds than the other species described in this paper. It seems likely that the basal Cretaceous of the Miquihuana region is equivalent to some part of the lower member of the Taraises formation.

PALEOGEOGRAPHIC RELATIONSHIPS

Burckhardt (2, pp. 86–90) has shown that in the region west of Cuidad Victoria the Upper Jurassic seas transgressed on red beds of probable Permo-Triassic age but in the vicinity of Miquihuana surrounded an island separated from a land mass to the east by a narrow strait. The seas were shallow, and at times lagoonal conditions existed. Toward the end of the Jurassic the sea withdrew slightly and then in early Cretaceous time readvanced, completely covering the island by Valanginian time and the land mass to the east at least as early. During the Lower Cretaceous subsidence occurred until several thousand feet of limestone had accumulated, but the sea bottom remained fairly shallow and reef organisms flourished during the latter part of the period.

SYSTEMATIC DESCRIPTIONS

Phylum MOLLUSCA

Class CEPHALOPODA

Genus ROGERSITES Spath, 1924

ROGERSITES FILIFER Imlay, n. sp.
Plate 73, figures 1, 2; plate 74, figures 4, 5

Fairly large forms; whorl subcircular in section, wider than high, embracing to umbilical tubercle; flanks gently convex, venter broadly convex. Umbilicus narrow and deep, wall high and vertical, shoulder abruptly rounded.

Umbilical wall bears about 20 weak ribs, which incline strongly backward and terminate on the umbilical shoulder in rather low tubercles. From the tubercles pass bundles of four to five threadlike ribs, which incline forward strongly on the flanks but cross the venter transversely. Bifurcation occurs rarely. Bundles separated by one or two intercalary ribs. Interspaces much wider than ribs. Numerous constrictions on each whorl. Suture line unknown.

Greatest diameter of holotype, about 115 mm.; width of umbilicus, 24.5 mm.; height of last whorl, 56 mm.; thickness of last whorl, 58 mm.

Rogersites filifer may be readily recognized by its threadlike ribbing. It greatly

resembles *Rogersites densicostatus* (Wegner) (21, p. 82, pl. 16, fig. 3) but, judging from the figures of the latter, has finer ribs and more numerous, more acute umbilical tubercles.

Holotype, U.M. 17940; paratype, U.M. 18549, Museum of Paleontology, University of Michigan.

Occurrence.—Holotype from middle part of unit 5 of section on west flank of San Lazaro anticline, about 0.5 mile (1 km.) south of pass on San Lazaro-Zaragosa trail, Nuevo León, Mexico. Paratype from unit 8 of section on west bank of Arroyo San Lazaro about 1 mile north of San Lazaro, Nuevo León, Mexico.

ROGERSITES BAKERI Imlay, n. sp.
Plate 70, figure 1

The species is represented by five specimens. Fairly large forms; whorl subcircular in section, wider than high, embracing to umbilical tubercles; flanks gently convex, venter broadly rounded. Umbilicus narrow and deep, wall high and vertical, shoulder fairly abruptly rounded.

Umbilical wall with 11 to 12 very weak ribs, which incline backward and terminate in small acute umbilical tubercles, which are slightly elongated radially. From the tubercles pass bundles of four, rarely five, acute ribs, which incline forward slightly on flanks but cross the venter transversely. Bundles separated by one or two intercalary ribs. Bifurcation common on lower part of flanks, resulting in about 120 ribs on venter of outer whorl. Interspaces much wider than ribs. About six or seven fairly pronounced constrictions on each whorl. Suture line unknown.

Greatest diameter of holotype, 83 mm.; width of umbilicus, 17.5 mm.; height of last whorl near anterior end, 34 mm.; thickness of last whorl, 46 mm. (?).

At first glance *Rogersites bakeri* appears to be very similar to *R. sanlazarensis*, but the former has fewer umbilical tubercles, more ribs per bundle, and greater frequency of rib bifurcation. *Rogersites prorsiradiatus* has coarser ornamentation and a wider umbilicus.

Holotype, U.M. 18555; paratype, U.M. 18554, Museum of Paleontology, University of Michigan.

Occurrence.—Unit 8 of section on the west bank of Arroyo San Lazaro about a mile north of San Lazaro, Nuevo León, Mexico.

ROGERSITES SANLAZARENSIS Imlay, n. sp.
Plate 74, figure 1; plate 72, figures 1–3

This species is represented in the University of Michigan collections by 10 specimens ranging in size from forms as large as the holotype to forms about an inch in diameter. The following description is based on mature specimens unless otherwise stated.

Fairly large forms; whorl semilunar in section, much wider than high, embracing to umbilical tubercles; flanks gently convex, venter broadly rounded. Umbilicus deep and fairly narrow, wall high and vertical, shoulder abruptly rounded.

Umbilical wall with about 18 fairly weak ribs, which incline backward and terminate in moderately small umbilical tubercles, which are elongated radially. From the tubercles pass bundles of three to four strong acute ribs, which incline forward rather strongly on flanks but cross venter transversely. Bundles separated by one to two intercalary ribs. Bifurcation occurs rarely on flanks. About 110 ribs on venter of outer whorl of holotype. Interspaces much wider than ribs. About six constrictions on each whorl. Suture line unknown.

Immature forms are very much like

EXPLANATION OF PLATE 70

FIG. *1*—*Rogersites bakeri* Imlay, n. sp. Holotype, U.M. 18555, ×1. (p. 560)
2–6—*Rogersites paucicostatus* Imlay, n. sp. *2–4* Paratype, U.M. 19559; *5* paratype, U.M. 18558; *6* holotype, U.M. 18033; ×1. (p. 561)

Imlay, Neocomian Cephalopods from Mexico

Imlay, Neocomian Cephalopods from Mexico

adult forms in shape and coarseness of sculpture. The bundles consist of three ribs, which do not bifurcate and are never separated by more than one intercalary rib.

Greatest diameter of holotype, 89 mm.; width of umbilicus, 19.5 mm.; height of last whorl, 37.5 mm.; thickness of last whorl, 54 mm.

This species is very similar to *Rogersites atherstoni* (Sharpe) (16, pl. 23, fig. 1a, b; 14, pp. 187, 193) but its flank ribs are finer and more closely spaced. *Rogersites prorsiradiatus* has fewer and stronger umbilical tubercles.

Holotype, U.M. 18063; paratypes, U. M. 18557, 18556, Museum of Paleontology, University of Michigan.

Occurrence.—Unit 8 of section on west bank of Arroyo San Lazaro about 1 mile north of San Lazaro, Nuevo León, Mexico.

ROGERSITES PRORSIRADIATUS

Imlay, n. sp.

Plate 71, figures 1–7

This species is represented by 27 specimens, which show various stages of growth. Unless otherwise stated the description refers to adult forms.

Fairly large forms; whorl subovate in section, wider than high, embracing to umbilical tubercles; flanks gently convex, venter broadly rounded. Umbilicus deep and fairly narrow, wall high and vertical, shoulder abruptly rounded.

Umbilical wall with 14 to 15 weak ribs, which incline backward and terminate in fairly strong umbilical tubercles. From the tubercles pass bundles of three to four narrowly rounded ribs, which incline forward rather strongly on flanks but cross venter transversely. Bundles separated by one or two intercalary ribs. In small forms bifurcation is rare. On large forms bifurcation is rather common. About 105 ribs on outer whorl of holotype. Interspaces much wider than ribs. About six or seven constrictions on each whorl. Suture line unknown. On immature forms the whorl section is higher than wide, and the ribs are rather closely spaced.

Greatest diameter of holotype, 100 mm.; width of umbilicus, 22 mm.; height of last whorl, 46 mm.; thickness of last whorl, 58 mm. (?).

Comparisons with *Rogersites bakeri* and *R. sanlazarensis* are given under their descriptions. *R. atherstoni* (Sharpe) (16, pl. 23; figs. 1a–b) is distinguished by lack of bifurcating ribs.

Holotype, U.M. 18560; paratypes, U.M. 18561, 18562, 18021, 18563, 18025, Museum of Paleontology, University of Michigan.

Occurrence.—Unit 8 of section on west bank of Arroyo San Lazaro about 1 mile north of San Lazaro, Nuevo León, Mexico.

ROGERSITES PAUCICOSTATUS

Imlay, n. sp.

Plate 70, figures 2–6

Large forms; whorls subovate in section, wider than high, embracing to umbilical tubercles; venter arched. Umbilicus deep and fairly narrow, wall high and vertical, shoulder abruptly rounded.

Umbilical wall with 11 broad faint ribs, which terminate in prominent umbilical tubercles. From tubercles pass bundles of strong rounded ribs ranging from two to three in immature forms to three to four in adult forms. One or two intercalary ribs between bundles. Interspaces much wider than ribs. About 65 ribs on outer whorl of holotype. Suture line unknown.

This species is easily distinguished from all described species by the small number of its tubercles and ribs.

Holotype, U.M. 18033; paratypes,

EXPLANATION OF PLATE 71

FIGS. *1–7*—*Rogersites prorsiradiatus* Imlay, n. sp. *1*, Paratype, U.M. 18561; *2*, paratype U.M. 18562; *3*, *4*, holotype, U.M. 18560; *5* paratype, U.M. 18021; *6*, *7*, paratype, U.M. 18563; ×1. (p. 561)

U.M. 18558, 18559, Museum of Paleontology, University of Michigan.

Occurrence.—Unit 8 of section on west bank of Arroyo San Lazaro about 1 mile north of San Lazaro, Nuevo León, Mexico.

ROGERSITES TENUICOSTATUS
Imlay, n. sp.
Plate 73, figures 3–9

This species is represented by 16 specimens, of which one form (pl. 73, figs. 6, 7) shows apertural impressions.

Moderately small forms for genus; whorl subovate in section, wider than high, embracing to umbilical tubercles except near the aperture; venter broadly arched. Umbilicus moderately narrow and deep, wall steeply inclined, shoulder rather gently rounded.

Umbilical wall marked by 16 to 19 moderately prominent ribs, which incline backward and terminate in acute umbilical tubercles. From the tubercles pass bundles of two or three prominent acute nonbifurcating ribs, which incline forward on the lower part of flanks but cross venter transversely. On anterior third of last whorl the forward curvature is most conspicuous. In bundles of three ribs the anterior ribs are strongly to faintly connected with the tubercles, and some are completely detached. The coarseness of ribbing varies somewhat on different specimens. On outer whorl of holotype there are about 57 ribs. Interspaces rounded and very broad. Constrictions faint. Suture line not preserved.

This species may be recognized by its coarse ornamentation and the forward inclination of the ribs near the aperture.

Holotype, U.M. 18019; paratypes, U.M. 18551, 18553, 18552, 18550, Museum of Paleontology, University of Michigan.

Occurrence.—Unit 8 of section on west bank of Arroyo San Lazaro about 1 mile north of San Lazaro, Nuevo León, Mexico.

Genus VALANGINITES Sayn, 1907

VALANGINITES TIJERENSIS
Imlay, n. sp.
Plate 72, figures 4, 5

Form globular; whorl section semilunar, much wider than high; venter broadly arched. Umbilicus very narrow and moderately deep; wall steep, shoulder rather abruptly rounded. Anterior end of shell marked by pronounced apertural constriction.

Upper part of umbilical wall bears 10 short broad ribs, which terminate in small acute umbilical tubercles. From the tubercles pass bundles of three to five low, broadly rounded ribs, which coarsen rapidly anteriorly. Rib bundles separated by one or two intercalary ribs. There are four faint constrictions on the holotype.

Holotype somewhat distorted. Greatest diameter, 36 mm. (?); height of whorl, 17 mm.; thickness of whorl, 28 mm.

Holotype, U.M. 18030, Museum of Paleontology, University of Michigan.

Occurrence.—Unit 8 of section on west bank of Arroyo San Lazaro about a mile north of San Lazaro, Nuevo León, Mexico.

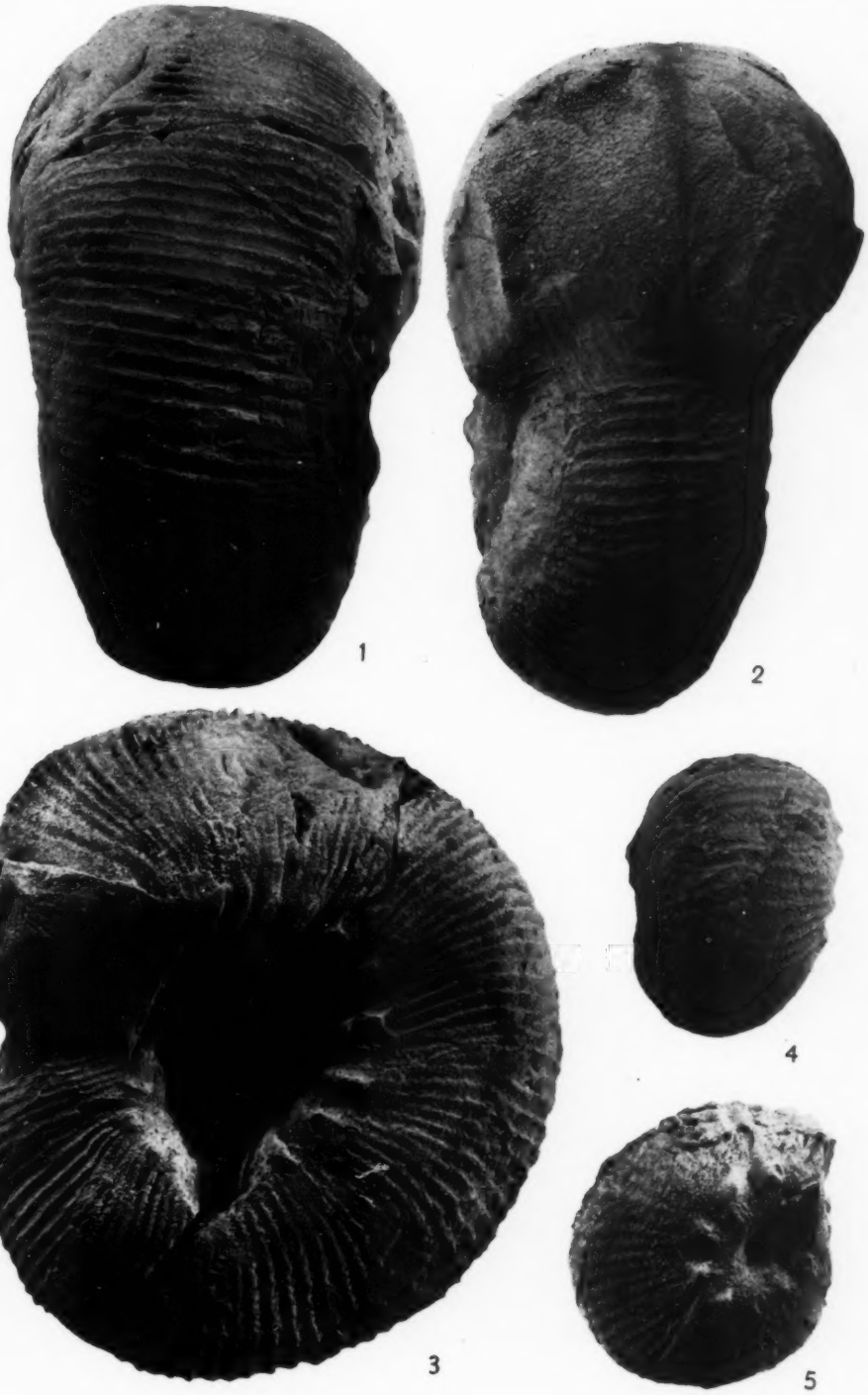
Genus THURMANNITES Kilian, 1913

THURMANNITES ANGUSTICOSTATUS
Imlay, n. sp.
Plate 75, figures 3–6; plate 82, figure 8

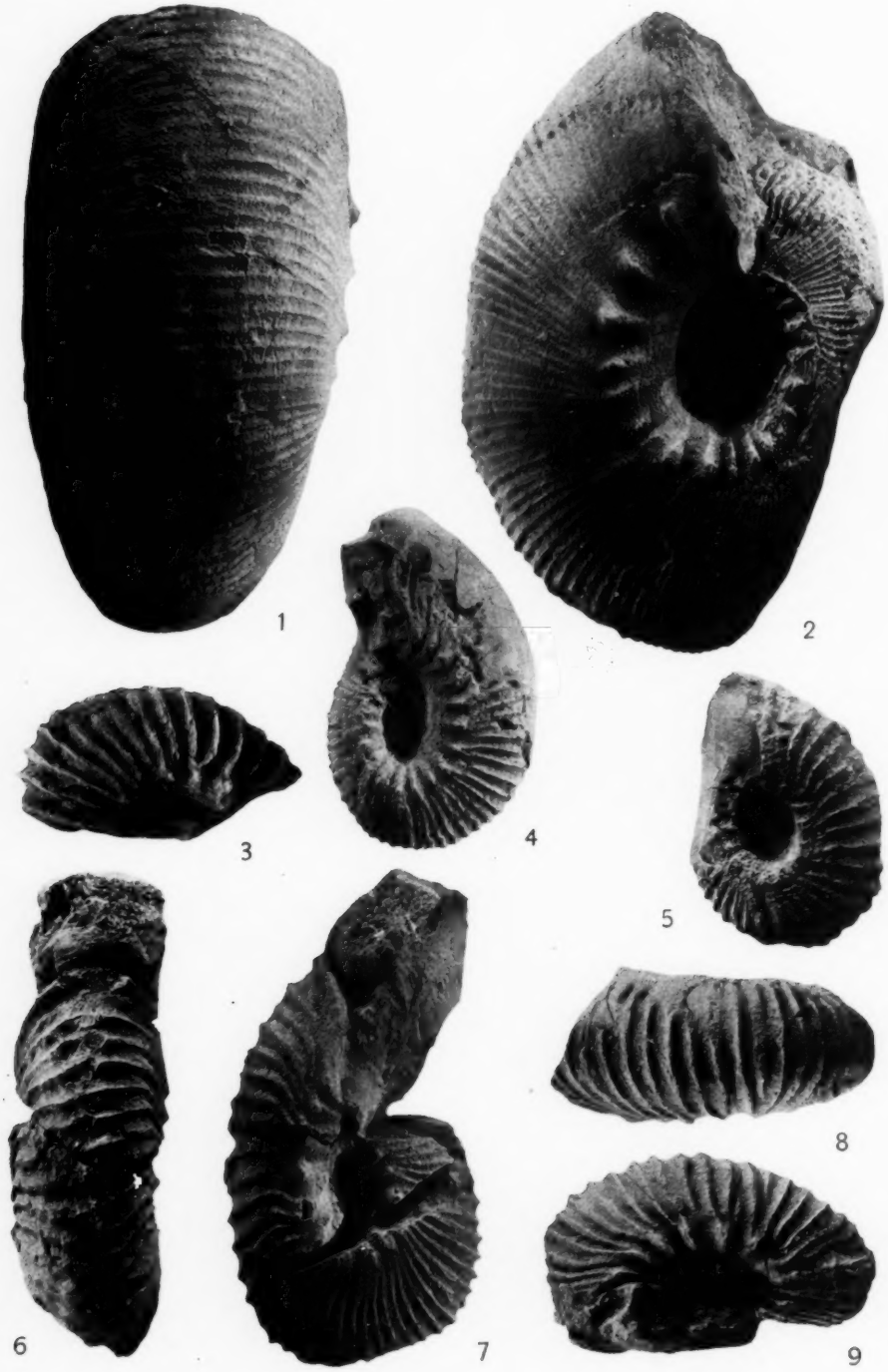
This species is represented by 12 specimens. Form gigantic, discoidal; whorl section subquadrate, much higher than wide in very small forms but becoming nearly as wide as high in adult forms; whorls embracing about three-fifths; lower three-fifths of flanks somewhat

EXPLANATION OF PLATE 72

FIGS. *1–3—Rogersites sanlazarensis* Imlay, n. sp. Holotype, U.M. 18030, ×1. (p. 560)
4, 5—Valanginites tijerensis Imlay, n. sp. Holotype, U.M. 18030, ×1. (p. 562)



Imlay, Neocomian Cephalopods from Mexico



Imlay, Neocomian Cephalopods from Mexico

flattened, upper part rounds fairly abruptly into the broad gently convex venter. Umbilicus fairly wide and shallow, wall nearly vertical, shoulder abruptly rounded.

In the earliest known stage (pl. 75, figs. 4–6), strong acute ribs start singly or in pairs, or in threes from distinct umbilical tubercles, pass nearly radially across the lower part of the flanks, and then incline forward slightly. Many ribs remain simple, about half bifurcate near the middle of the flanks. Ventrally the ribs become swollen and terminate in blunt tubercles, which bound a fairly wide smooth midventral area. There are five or six deep constrictions.

At a slightly older stage the ribs cross the venter with only slight diminution. On the outer whorl of the holotype (pl. 75, fig. 3) the ribs are very high and narrow, most of them start singly on the umbilical wall, and there is a definite tendency toward differentiation into very strong tuberculiferous ribs and less strong nontuberculiferous ribs. About half of the ribs bifurcate along a zone about one-third of the way down the flank and bear both lateral and umbilical tubercles. The simple ribs become stronger ventrally but do not bear lateral tubercles, and many are not swollen on the umbilical shoulder. A slight thinning of the ribbing along the midventral line occurs even on the largest specimens. Dimensions of paratype 18031 and holotype, respectively: Greatest diameter, 50 mm., 125 mm.; height of whorl, 23 mm., 43 mm.; thickness of whorl (paratype), 18 mm.; umbilical width, 14 mm. (?), 52 mm.

Holotype, U.M. 16982; paratypes, U.M. 18031, 18608, 17189, Museum of Paleontology, University of Michigan.

Occurrence.—(1) Near base of Cretaceous section of reservoir locality at northeast limit of Miquihuana, Tamaulipas; (2) unit 8 of section on west bank of Arroyo San Lazaro about a mile north of San Lazaro, Nuevo León; (3) unit 4 of section on west flank of San Lazaro anticline about 0.6 mile (1 km.) south of pass on San Lazaro-Zaragosa trail, Nuevo León, Mexico.

THURMANNITES NOVIHISPANICUS

Imlay, n. sp.

Plate 78, figures 8, 9;
plate 79, figure 6

The species is represented by 10 fairly complete specimens and by many fragments.

Form discoidal, compressed; whorl section subelliptical, much higher than wide; inner whorls embracing about three-fourths, outer whorls about one-third; lower part of flanks flattened, upper part sloping gently to venter, which is truncated in immature forms and gently convex in mature forms.

Ornamentation of innermost whorls not definitely known, although one specimen probably represents an immature form of this species. It is characterized by *Kilianella*like ornamentation. The ribs originate singly or in pairs from distinct umbilical tubercles, are strongly falciform on the flanks, broaden ventrally, and terminate in backwardly inclined tubercles, which bound a narrow, smooth, slightly convex midventral area. At least one rib of each pair and most of the single ribs bifurcate near the middle of the flanks. Constrictions are numerous. The umbilicus is much narrower than is typical of *Kilianella*.

On the holotype (pl. 78, figs. 8, 9) the upper part of the umbilical wall is marked by broad backwardly inclined ribs, which terminate in rather pronounced umbilical tubercles. Most of the

EXPLANATION OF PLATE 73

FIGS. *1, 2—Rogersites filifer* Imlay, n. sp. Paratype, U.M. 18549, ×1. (p. 559)
3–9—Rogersites tenuicostatus Imlay, n. sp. *3*, Paratype, U.M. 18551; *4*, paratype U.M. 18553; *5*, paratype, U.M. 18552; *6, 7*, holotype, U.M. 18019; *8, 9*, paratype, U.M. 18550; ×1. (p. 562)

flank ribs originate in pairs from the umbilical tubercles, incline forward, are only slightly falciform, and bifurcate at or slightly above the middle of the flanks. Short intercalary ribs occur on the upper third of the flanks. The cross section of the ribs tends to be broadly triangular rather than rounded. At the posterior end of the outer whorl the ribs give rise to ventral tubercles but continue across the venter with considerable reduction in strength. Toward the anterior end of the outer whorl the ribs become stronger on the venter, and the ventral tubercles disappear. There are many faint constrictions.

On specimens larger than the holotype most of the flank ribs originate singly at rather pronounced umbilical tubercles. A few start on the umbilical wall and do not form swellings on the umbilical shoulder. The ribs are broadly triangular in cross section, inclined forward on the flanks, are slightly falciform, and only slightly reduced in strength on the venter. Intercalary ribs are common on the upper half of the flanks. Most ribs bifurcate about one-third the way down the flanks. On the largest specimens strong lateral tubercles appear at the bifurcating points of every third or fourth rib (e.g. paratype U.M. 17973 at a diameter of about 185 mm.), which are stronger than the intermediate nontuberculiferous ribs.

Dimensions of holotype and paratype 17190, respectively: Greatest diameter, 92 mm., 141 mm.; height of whorl, 40 mm., 52 mm.; thickness of whorl (holotype), 26 mm.; umbilical width, 25.5 mm., 51 mm.

Thurmannites novihispanicus is easily distinguished from *T. angusticostatus* by its higher whorl section and less vigorous ornamentation.

Holotype, U.M. 16899; paratypes, 17190, 17192, 17188, 17973, Museum of Paleontology, University of Michigan.

Occurrence.—(1) Near base of Cretaceous section at reservoir locality at northeast limit of Miquihuana; (2) unit 4 of section west-northwest of Miquihuana; (3) base of unit 3 of section 1 mile east of Miquihuana; (4) questionably from unit 8 of section on west bank of Arroyo San Lazaro about a mile north of San Lazaro, Tamaulipas and Nuevo León, Mexico.

Thurmannites miquihuanensis Imlay, n. sp.

Plate 76, figure 1; plate 77, figure 7

Several specimens belong to a species similar to *T. novihispanicus* but having a lower rounder cross section and slightly coarser ornamentation. On the inner whorls most of the ribs originate singly on the umbilical wall, become somewhat swollen on the shoulder, incline slightly forward on the flanks, and bifurcate fairly regularly slightly above the middle of the flanks. On the outer whorls about every third to fifth rib is much stronger than the intervening ribs and bears a large lateral tubercle, from which fork two or three ribs. Most of the weaker intervening ribs are unbranched and nontuberculated. Most of them begin on the umbilical wall, but some begin near the middle of the flanks. Greatest diameter of holotype, 230 mm.; height of whorl, 82 mm.; thickness of whorl, 75 mm.; width of umbilicus, 90 mm.

Holotype, U.M. 16897; paratypes, U.M. 17976, 18606, 18270, 16898, Museum of Paleontology, University of Michigan.

Occurrence.—(1) Collection B.5, unit 4 of section 1 mile east of Miquihuana; (2) near base of Cretaceous section at

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Explanation of Plate 74

Fig. *1—Rogersites sanlazarensis* Imlay, n. sp. Paratype, U.M. 18557, ×1. (p. 560)
2, 3—Pleuromya sp. *2*, U.M. 18720; *3*, U.M. 18791; ×1. (p. 567)
4, 5—Rogersites filifer Imlay, n. sp. Holotype, U.M. 17940; ×1. (p. 559)
6, 7—Pecten sp. b. *6*, U.M. 18699; *7*, U.M. 18700; ×1. (p. 568)

Imlay, Neocomian Mollusks from Mexico

Imlay, Neocomian Mollusks from Mexico

reservoir locality at northeast limit of Miquihuana; (3) unit 4 of section on west flank of San Lazaro anticline.

THURMANNITES sp.

Plate 80, figures 3, 4

In the lower Neocomian collections from Miquihuana and San Lazaro are a number of fragments of *Thurmannites* showing very coarse ribbing and constituting a distinct and easily recognized species. It seems best not to name this species until more complete specimens are found.

The general form is probably like that of *Thurmannites angusticostatus*. The ribs are very high, rounded, widely spaced, originate singly or doubly from umbilical tubercles, or rise between tubercles, are somewhat falciform on the flanks and slightly reduced in strength along the midventral line. Most ribs are simple; a few ribs bifurcate just above the middle of the flank, and the bifurcation points are marked by strong tubercles.

U.M. 17187, 17602, 18604, 17981, 17191, Museum of Paleontology, University of Michigan.

Occurrence.—(1) Collection B.5, unit 4 of section 1 mile east of Miquihuana; (2) near base of Cretaceous section at reservoir locality at northeast limit of Miquihuana; (3) unit 4 of section west northwest of Miquihuana; (4) unit 4 of section on west flank of San Lazaro anticline.

Genus DISTOLOCERAS Hyatt, 1900

DISTOLOCERAS aff. D. PARRITENSE Imlay

Plate 81, figure 9

The genus is represented by one specimen, which is somewhat larger than any specimen of *D. parritense* from the Sierra de Parras of Coahuila. Its great similarity to that species suggests beds of lower Hauterivian age in the San Lazaro area.

U.M. 17941, Museum of Paleontology, University of Michigan.

Occurrence.—Lower to middle part of unit 5 of section on west flank of San Lazaro anticline. Section measured about 0.6 mile (1 km.) south of pass on San Lazaro-Zaragosa trail, Nuevo León, Mexico.

Genus FAVRELLA DOUVILLE, 1909

FAVRELLA sp.

Plate 80, figures 1, 2

Only one fragment of this genus is present in the University of Michigan collections.

Shell evolute; whorl section subovate, almost as wide as high; flanks gently convex but rounding rather abruptly into the nearly flat venter. Umbilical wall very steep, moderately high, shoulder strongly rounded.

Surface ornamented with strong widely spaced ribs, of which most start near the umbilical suture, are strongly falciform on the flanks, and form an acute angle on the venter. Ribs become stronger ventrally but are slightly weakened on the midventral line. Some main ribs bifurcate near the middle of the flank, and others are separated by short intercalary ribs which are as strong on the venter as are the main ribs.

Favrella patagoniensis Favre (5, p. 619, pl. 32, figs. 9, 10) is very similar to the Mexican species, but its ribs are somewhat weaker and closer spaced. *Favrella angulatiformis* (Behrendsen) (1, p. 16, pl. 4, figs. 2a–c; 20, p. 460, pl. 57, fig. 366) at a comparable size has weaker, less falciform ribs.

U.M. 18922, Museum of Paleontology, University of Michigan.

Occurrence.—Unit 8 of section on the west bank of Arroyo San Lazaro about

EXPLANATION OF PLATE 75

FIG. *1*—*Pecten* sp. a. U.M. 18703, ×1. (p. 568)
2—*Pecten* sp. b. U.M. 18701, ×1. (p. 568)
3–6—*Thurmannites angusticostatus* Imlay, n. sp. *3*, Holotype, U. M. 16982; *4–6*, paratype U.M. 18031; ×1. (p. 562)

a mile north of San Lazaro, Nuevo León, Mexico.

Class Pelecypoda

Genus Exogyra Say, 1819

Exogyra reedi Imlay, n. sp.

Plate 77, figures 1–6; plate 78, figures 1–7

This species is represented in the University collections by 53 specimens representing various sizes and growth stages.

Shell of adult moderately thick, medium-sized, elongated, ventral margin curved posteriorly.

Left valve much larger than the right valve, very convex; proximity of beak marked by attachment scar. Apical portion strongly incurved and more or less strongly bent laterally. A pronounced umbonal ridge extends from the beak backward in a curve conforming to the twist of the shell, becoming somewhat rounder toward the margin. This ridge is so high and narrow that the sides of the valve slope away at an angle of less than 90°. The posterior side descends much more steeply than the anterior side, and in some specimens is slightly concave. Character of hinge and muscle scars unknown. Surface marked by low growth lines, which are most prominent on the umbonal ridge.

Right valve with irregular surface, slightly concave, elongate, operculiform. Beak low and within the margin. Surface marked by faint growth lines.

Dimensions of paratype 18686 (pl. 78, figs. 4, 5): Length, 8.5 mm.; estimated height, 51 mm.; convexity, 13.5 mm. Paratype 18681 (pl. 77, figs. 1–3): Length, 17.0 mm.; estimated height, 62 mm.; convexity, 17.5 mm. Paratype 18664 (pl. 78, figs. 6, 7): Length, 21.0 mm.; estimated height, 67 + mm.; convexity, 21.0 mm. Holotype (pl. 78, figs. 1–3): Length, 24 mm. ±; estimated height, 117 mm.; convexity, 28.0 mm.

Exogyra reedi shows considerable variation in shape from a slender form like the holotype to a much stouter form. In the Sierra de Mapimi of eastern Durango, Kellum (10, pp. 1067–68) found a very similar species represented by many well-preserved specimens, in units B and 5 of the Torcer-Las Vigas series. In his collection A-34 a stout variety is represented by U.M. 15824 and in collection A-37 by U.M. 15924, but a slender variety is also represented by uncatalogued specimens. The same varieties as found by Kellum occur likewise at the base of the Cretaceous (?) section in the region of Barril Viejo, 30 miles southeast of Cuatro Ciengas, Coahuila, and were doubtless ascribed by Burckhardt (2, p. 145) to *Exogyra couloni* Defrance. This species of *Exogyra* from Barril Viejo and the Sierra de Mapimi probably comes from a different horizon than *Exogyra reedi*, as there are no species in common between the fauna of the Miquihuana area and the faunas of the abovementioned areas.

Holotype, U.M. 18663; paratypes, U.M. 18664, 18683, 18682, 18681, 18686, 18616, Museum of Paleontology, University of Michigan.

Occurrence.—(1) Collection 1 from unit 2, and collections 2, 3, and 4 from unit 3 of section 1 mile east of Miquihuana; (2) near base of Cretaceous at reservoir locality at northeast limit of Miquihuana; (3) units 3 and 4 of section west-northwest of Miquihuana, Tamaulipas, Mexico.

Exogyra putnami Imlay, n. sp.

Plate 81, figures 1–8

This species is represented by 41 specimens. Shell of adult fairly thick, elongate-ovate in outline, medium-sized. One broken specimen from the reservoir locality is nearly three times as large as the holotype.

Left valve much larger than the right valve, convex. Apical portion curved in-

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Explanation of Plate 76

Fig. 1—*Thurmannites miquihuanensis* Imlay, n. sp. Holotype, U.M. 16897, ×¾. (p. 564)

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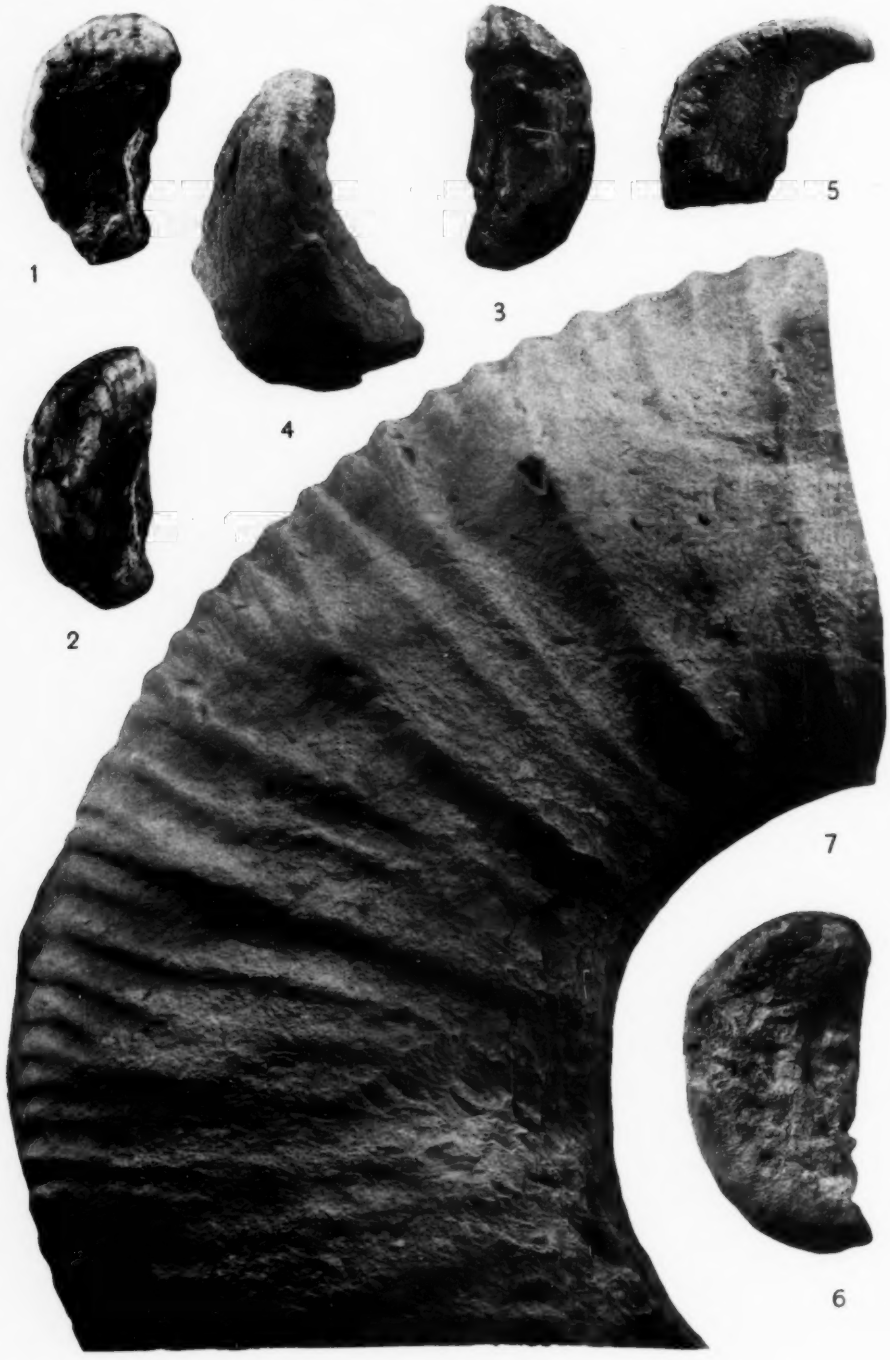
Imlay, Neocomian Cephalopods from Mexico



Imlay, Neocomian Mollusks from Mexico

ward very strongly; beak bent slightly laterally. A more or less clearly defined umbonal ridge extends from the beak backward in a curve conforming with the twist of the shell but becomes fairly rounded near the margin. The side of the valve posterior to the ridge descends steeply to the margin; the side anterior to the ridge rounds gently almost to the anterior margin and then descends very steeply. Internal characters unknown. Surface marked by moderately pronounced growth lines, which are most pronounced on the umbonal ridge.

Right valve operculiform, slightly concave, with an irregular surface. Beak low, slightly twisted, within margin. Surface marked by fairly strong growth lines.

Dimensions of paratype 18692 (pl. 81, fig. 4): Length, 21 mm.; estimated height, 60 mm.; convexity, 16 mm. Paratype 18666: Length, 29 mm.; estimated height, 61+ mm.; convexity, 20 mm. Paratype 18665 (pl. 81, figs. 7, 8): Length, 28 mm.; estimated height, 88+ mm.; convexity, 18 mm. Holotype (pl. 81, figs. 1–3): Length, 31.5 mm.; estimated height, 80 mm.; convexity, 26 mm.

Exogyra putnami somewhat resembles *E. reedi* but is distinguished by its obtuse umbonal ridge, more strongly incurved umbo, less strongly deflected beaks, and more regular form.

Holotype, U.M. 18690; paratypes, U.M. 18665, 18689, 18684, 18666, 18692, Museum of Paleontology, University of Michigan.

Occurrence.—(1) Collections 2, 3, and 4 from unit 3 of section 1 mile east of Miquihuana; (2) near base of Cretaceous at reservoir locality at northeast limit of Miquihuana; (3) units 3 and 4 of section west-northwest of Miquihuana, Tamaulipas, Mexico.

EXOGYRA TAMAULIPANA Imlay, n. sp.
Plate 79, figures 1–5

Twelve specimens belong to a moderately small, stout species with a subovate outline.

Left valve much larger than right valve, convex; proximity of beak marked by attachment scar. Apical portion incurved a little and bent rather strongly laterally. A fairly strong umbonal ridge extends from the beak backward to the margin, conforming with the curvature of the shell. The side of the valve posterior to the ridge descends steeply to the margin; the side anterior to the ridge rounds evenly to the margin. Surface marked by fairly pronounced growth lines.

Right valve concave. Beak low, marginal, slightly twisted, bent laterally. Surface marked by strong growth lines.

Dimensions of left valve of holotype (pl. 79, figs. 1, 3): Length, 31 mm.; estimated height, 65 mm.; convexity, 19 mm.

This species may be distinguished from *Exogyra putnami* by its lower stouter form and much less incurved beak.

Holotype, U.M. 18676; paratypes, U.M. 18668, 18691, Museum of Paleontology, University of Michigan.

Occurrence.—(1) Unit 3 of section west-northwest of Miquihuana; (2) collections 2, 3, and 4 of unit 3 of section 1 mile east of Miquihuana, Tamaulipas, Mexico.

Genus PLEUROMYA Agassiz, 1842

PLEUROMYA sp.
Plate 74, figures 2, 3

A large number of internal molds bear a resemblance to *Pleuromya inconstans* C. and A. (3, pp. 10–12, lam. 5, figs. 15–16; lam. 6, figs 1–4) but are too poorly preserved for specific determination.

EXPLANATION OF PLATE 77

FIGS. *1–6—Exogyra reedi* Imlay, n. sp. *1–3*, Paratype, U.M. 18681; *4*, *6*, paratype, U.M. 18683; *5*, paratype, U.M. 18616; ×1. (p. 566)

7—Thurmannites miquihuanensis Imlay, n. sp. Part of paratype, U.M. 17976, ×1. (p. 564)

U.M. 18629, 18639, 18720, 18719, Museum of Paleontology, University of Michigan.

Occurrence.—(1) Collection B.1 from unit 2 and collection B.2 at base of unit 3 of section 1 mile east of Miquihuana, Tamaulipas.

Genus PECTEN MÜLLER, 1776

PECTEN sp. a

Plate 75, figure 1

Shell small, subcircular in outline, subequilateral, depressed convex, the height in some specimens slightly greater than the length. Beak small, projecting slightly above the middle of the hinge line. Ears nearly equal in size, sharply separated from the body of the shell by sulci. The sulci are coincident with the upper margins of the dorsal slopes and diverge from the beaks at an angle of about 105° to 110°. Shoulders situated a little above the midheight. Surface of shell marked by very fine closely spaced concentric lamellae, which are barely visible macroscopically.

This species is represented by 16 specimens, of which few show traces of ears.

U.M. 18704, 18705, 18703, Museum of Paleontology, University of Michigan.

Occurrence.—Collection B.2 at base of unit 3, and collection B.1 from unit 2 of section 1 mile east of Miquihuana, Tamaulipas.

PECTEN sp. b

Plate 74, figures 6, 7; plate 75, figure 2

Shell fairly small, subequilateral, subovate in outline, higher than long. Valves depressed convex but with fairly prominent umbonal regions. Beaks barely project above the hinge. Ears nearly equal in size, separated from the body of the shell by sulci. The upper margins of the dorsal slopes diverge from the beak at an angle of 80° to 85° and are nearly straight. Shoulders situated a little above the midheight. Surface of shell marked by very fine closely spaced concentric lamellae.

This species is represented by 33 specimens. It is distinguished from *Pecten* sp. a by its greater height and convexity.

U.M. 18701, 18699, 18700, Museum of Paleontology, University of Michigan.

Occurrence.—Collection B.1 from unit 2, collection B.2 at base of unit 3, and collection B.3 from middle part of unit 3 of section 1 mile east of Miquihuana, Tamaulipas.

Phylum BRACHIOPODA

Class ARTICULATA

Genus ANTIPTYCHINA Zittel, 1880

ANTIPTYCHINA? MÜLLERRIEDI

Imlay n. sp.

Plate 82, figures 9–24; text figure 4

Shell subpentagonal to ovatepentagonal in outline. Pedicle valve more convex than brachial. Ventrally biplicate to nearly uniplicate. Biplication commences from one-third to one-half of the length of the valve from the umbo. Umbo of brachial valve incurved. Lateral commissure slopes dorsally at a slight angle and is then abruptly recurved ventrally near the anterior margin. Linguiform extension pronounced only on largest specimens. Umbo of pedicle valve rounded, incurved and nearly in contact with the brachial valve. Beak ridges subangular, mesothyrid (?), extending nearly to the posterolateral margin almost parallel to the hinge. Apical angle 105° to 115°. Holotype 15.4 mm. long, 15 mm. wide, and 11.1 mm. thick. Shell densely punctate; marked by fine concentric growth lines.

The median septum is stout; extends slightly more than one-third of the length of the brachial valve, supports the hinge plates throughout their length, and bears connecting bands about 1 mm. from its

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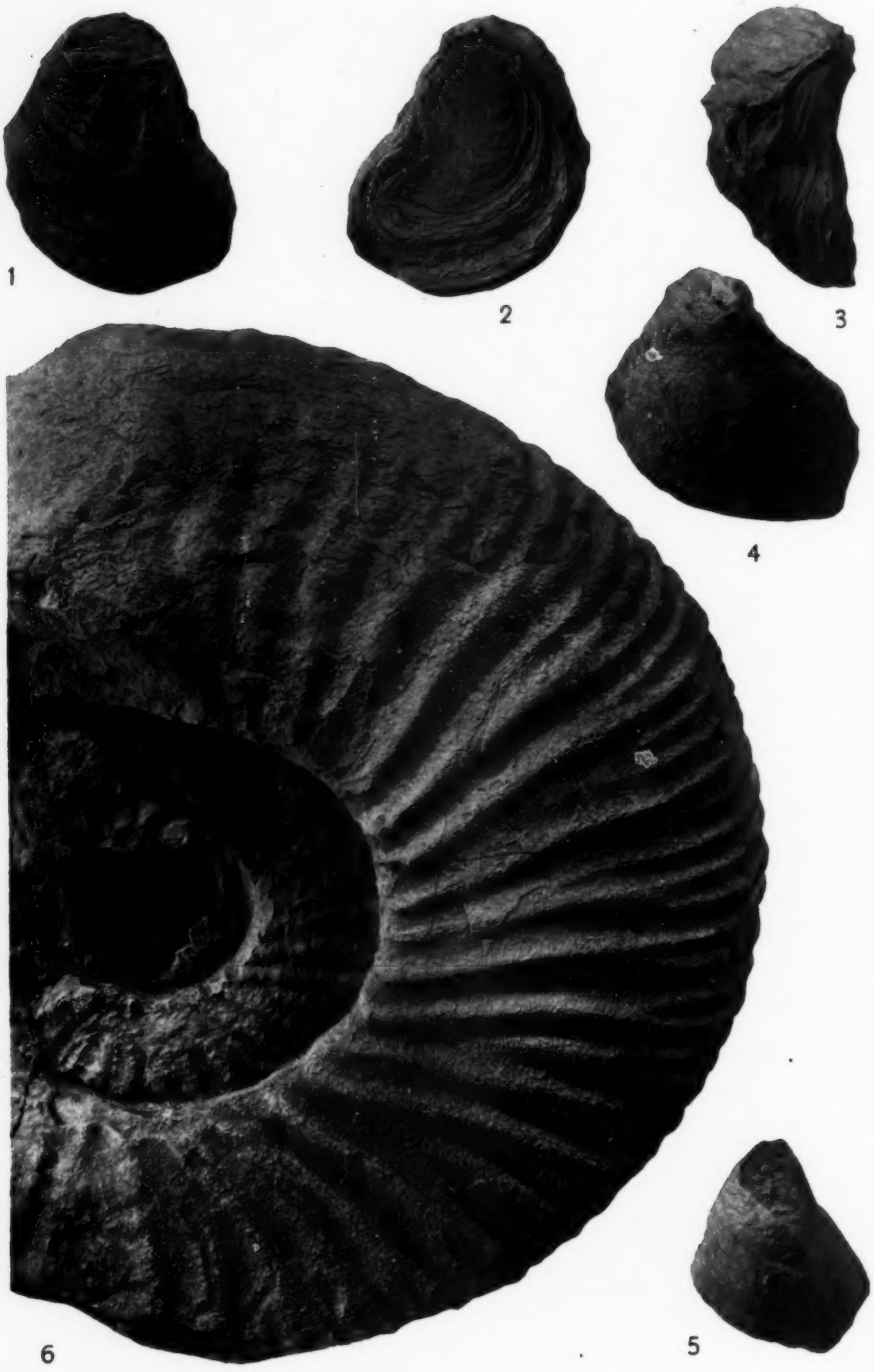
EXPLANATION OF PLATE 78

FIGS. *1–7—Exogyra reedi* Imlay, n. sp. *1–3*, Holotype, U.M. 18663; *4, 5*, paratype, U.M. 18686; *6, 7*, paratype, U.M. 18664; ×1. (p. 566)

8, 9—Thurmannites novihispanicus Imlay, n. sp. Holotype, U.M. 16899, ×1. (p. 563)

Imlay, Neocomian Mollusks from Mexico



Imlay, Neocomian Mollusks from Mexico

anterior end. The septalium is moderate in depth and has a slight median elevation. Inner socket ridges prominent, overlapping sockets, and interlocking with a sulcus on each tooth. Crural bases probably given off ventrally. In large individuals the beak regions have considerable

Holotype, U.M. 18752; paratypes, U.M. 18742, 18744, 18745, 18754, 18733, Museum of Paleontology, University of Michigan.

Occurrence.—Near base of Cretaceous section at the reservoir locality at northeast limit of Miquihuana, Tamaulipas.

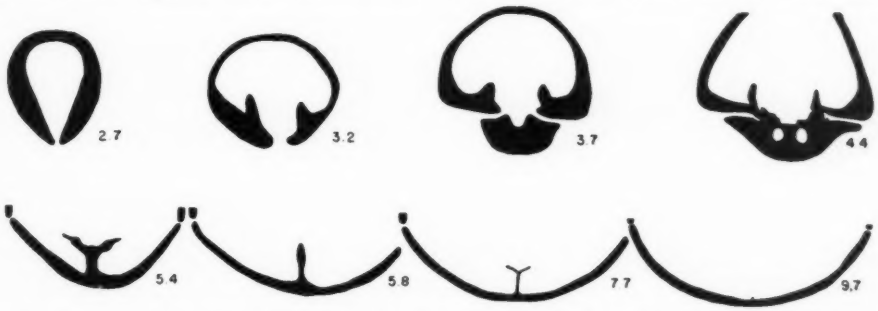


FIG. 4—Transverse sections of *Antiptychina? müllerriedi* Imlay. Length of shell, 18.2 mm. Distance of sections from beak of pedicle valve in millimeters. ×2.

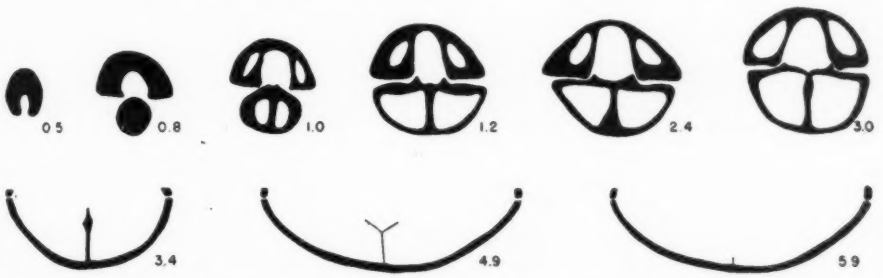


FIG. 5—Transverse sections of *Antiptychina? lata* Imlay. Length of shell, 14 mm. Distance of sections from beak of pedicle valve in millimeters. ×2.

callus in which the dental lamellae are embedded.

This species is represented in the University of Michigan collections by about 150 specimens, which show some variation in dimensions and in degree of biplication. The holotype is a typical individual. Most specimens are slightly longer than wide. The degree of biplication bears no apparent relation to the size or shape of the shell.

ANTIPTYCHINA? LATA Imlay, n. sp.
Plate 82, figures 1–7; text figure 5

Shell broadly ovate in outline. Pedicle valve more convex than brachial. Ventrally weakly biplicate. Biplication commences from one-half to two-thirds of the length of the valve from the umbo. Lateral commissure slopes dorsally at a slight angle and is then abruptly recurved ventrally near the anterior margin. Umbo of pedicle valve rounded,

EXPLANATION OF PLATE 79

FIGS. *1–5—Exogyra tamaulipana* Imlay, n. sp. *1–3*, Holotype, U.M. 18676; *4*, paratype, U.M. 18691; *5*, paratype, U.M. 18668; ×1. (p. 567)
6—Thurmanniles novihispanicus Imlay, n. sp. Paratype, U.M. 17190, ×1. (p. 563)

stout, incurved, and nearly in contact with the brachial valve. Beak ridges subangular, mesothyrid. Apical angle about 120°. Shell densely punctate, and marked by numerous fine concentric growth lines. Holotype 12.2 mm. long, 14.5 mm. wide, 8.5 mm. thick.

The median septum is fairly strong, extends a little less than one-half of the length of the brachial valve, supports the hinge plates throughout their length, and bears connecting bands about 2 mm. from its anterior end. The septalium is fairly shallow and posteriorly bears a slight median elevation. Inner socket ridges prominent, not overlapping sockets. Dental lamellae strong, divergent, and embedded in considerable callus.

This species is represented by five specimens, of which one was sectioned. It is readily distinguished from "*Antiptychina*" *müllerriedi* by its greater breadth and weaker biplication.

Holotype, U.M. 18739; paratypes, U.M. 18740, 18783, 18735, Museum of Paleontology, University of Michigan.

Occurrence.—Near base of Cretaceous section at the reservoir locality at northeast limit of Miquihuana, Tamaulipas.

Genus RHYNCHONELLA FISCHER von Waldheim, 1809 (sensu lato)

"RHYNCHONELLA" MIQUIHUANENSIS Imlay, n. sp.

Plate 83, figures 14–21; text figure 6

Shell trigonal in outline. Brachial valve fairly highly convex, with well-defined median fold anteriorly, which is rather sharply demarcated from the convex flanks. Umbo of brachial valve much incurved. Pedicle valve moderately convex with broad, flattened median sinus, which develops about 7 mm. from the umbo and increases considerably in depth anteriorly. The linguiform extension is broadly U-shaped and tapers slightly forward. Umbo of pedicle valve acute, incurved, but well separated from the brachial valve. Beak ridges are subangular near the umbo; interareas broad; deltidial plates conjunct. Apical angle 100° to 110°. Foramen hypothyrid. Holotype about 14.7 mm. long, 16.6 mm. wide, 10.6 mm. thick.

Shell ornamented with 18 to 21 rounded costae, which radiate from the umbo and are curved on the flanks. The ribs are dim on the umbo,become strong anteriorly, and tend to be subangular near the anterior commissure. There are four costae in the sinus and five on the fold. Inconspicuous growth lines occur on the anterior part of the shell.

The median septum extends about three-fifths of the length of the brachial valve. It supports the hinge plates in the umbonal region, splits away from the septalial plates about 1.8 mm. from the umbo, and remains fairly strong throughout its length. The hinge sockets are fairly deep and are overlapped by the socket ridges. The hinge plates are not visibly demarcated from the short inner socket ridges. The crural bases are given off dorsally. The dental lamellae are short.

This species is represented by 16 specimens, all more or less compressed and distorted. Associated with it at the reservoir locality at Miquihuana is a very similar species, represented by two specimens, which has five costae in the sinus and six on the fold.

Holotype, U.M. 18738; paratypes, U.M. 18746, 18734, 18784, Museum of Paleontology, University of Michigan.

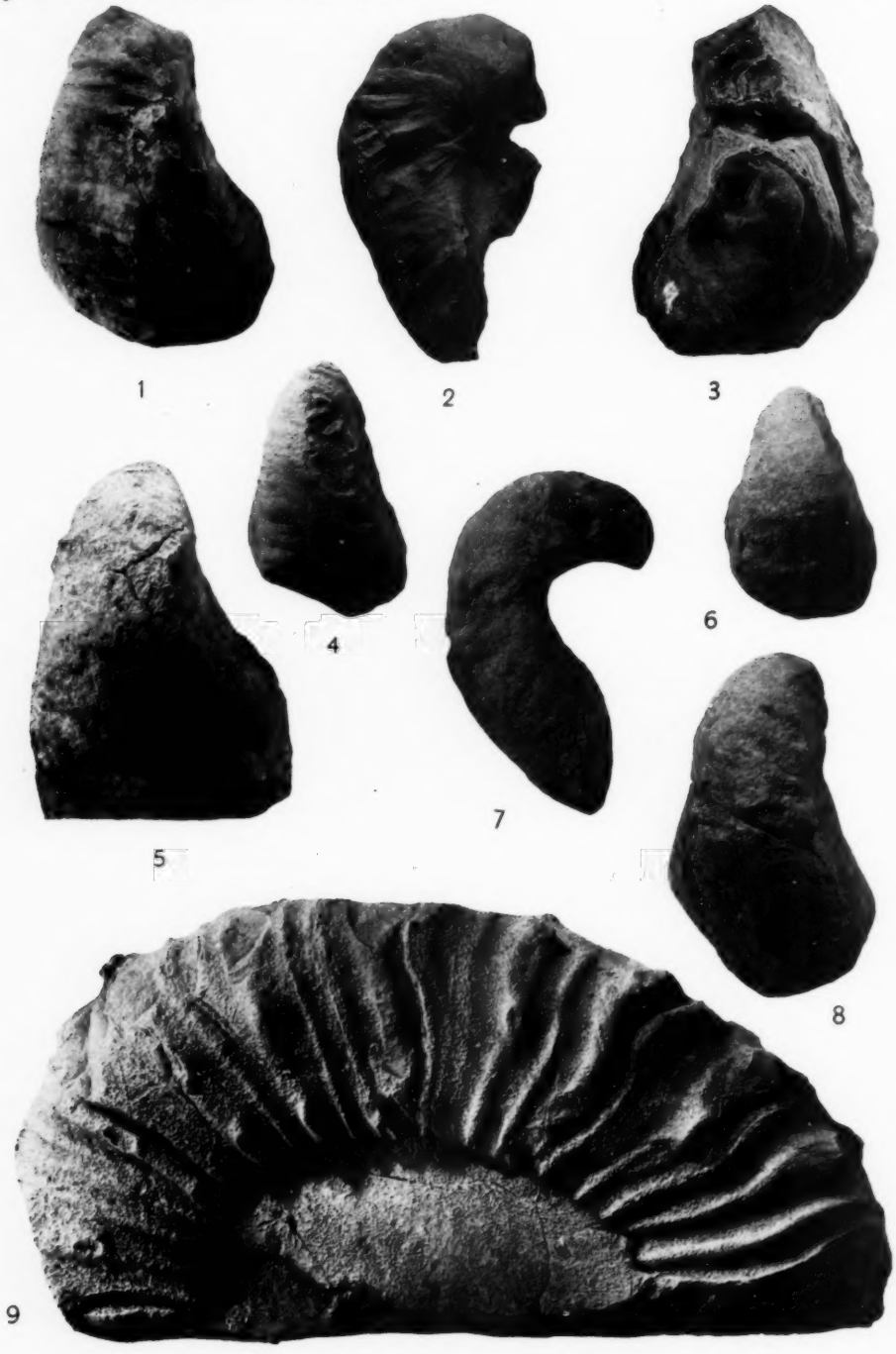
Occurrence.—Near base of Cretaceous section at reservoir locality at northeast limit of Miquihuana, Tamaulipas.

EXPLANATION OF PLATE 80

FIGS. *1, 2*—*Favrella* sp. U.M. 18622, ×1. (p. 565)

3, 4—*Thurmannites* sp. *3*, U.M. 18604; *4*, upper part of a whorl, U.M. 17981; ×1. (p. 565)

Imlay, Neocomian Cephalopods from Mexico



Imlay, Neocomian Mollusks from Mexico

Genus CYCLOTHYRIS McCOY, 1844

CYCLOTHYRIS? SUBTRIGONALIS
Imlay, n. sp.

Plate 83, figures 12, 13, 22–27;
text figure 7

Shell subtrigonal in outline. Both valves somewhat convex. Median fold sharply demarcated from convex flanks near anterior end. Umbo of brachial valve much incurved. Pedicle valve with fairly shallow sinus, which develops about 7 mm. from the umbo. Linguiform extension short and U-shaped. Umbo of pedicle valve acute, incurved, but well separated from the brachial valve. Beak ridges narrowly rounded; interareas fairly broad; deltidial plates conjunct. Apical angle 95° to 100°. Foramen hypothyrid. Holotype 14.2 mm. long, 13.5 mm. wide, 6.9 mm. thick.

Shell ornamented with 15 to 18 narrowly rounded costae, which radiate from the umbo and are curved on the flanks. Ribs dim on umbo but become strong near anterior commissure. There are three costae in the sinus and four on the fold. Growth lines are inconspicuous.

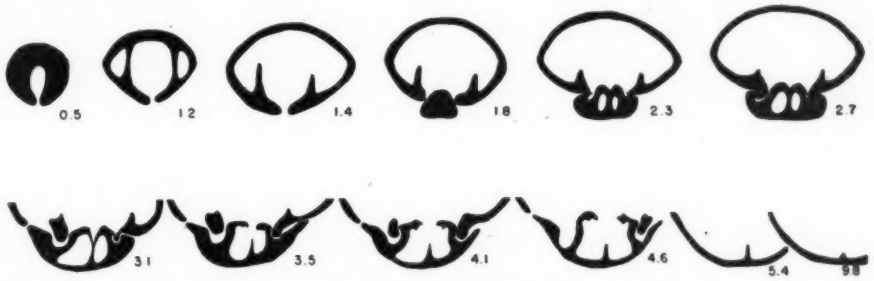


FIG. 6—Transverse sections of *"Rhynchonella" miquihuanensis* Imlay. Length of shell, 15.5 mm. Distance of sections from beak of pedicle value in millimeters. ×2.

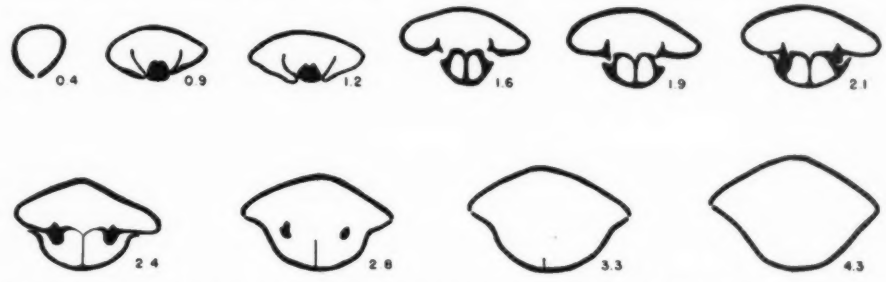


FIG. 7—Transverse sections of *Cyclothyris? subtrigonalis*. Length of shell, 15.6 mm. Distance of sections from beak of pedicle valve in millimeters. ×2.

The median septum extends a little more than one-fourth of the length of the brachial valve. It splits away from the hinge plate about 2 mm. from the umbo but persists for a distance of about 4 mm. It is rather weak and anterior to the hinge plates is very thin. The hinge sockets are fairly deep and are over-

EXPLANATION OF PLATE 81

FIGS. *1–8—Exogyra putnami* Imlay, n. sp. *1–3*, Holotype, U.M. 18690; *4*, paratype, U.M. 18692; *5*, paratype, U.M. 18689; *6*, paratype, U.M. 18684; *7*, *8*, paratype, U.M. 18665; ×1. (p. 566)

9—Distoloceras aff. *D. parritense* Imlay, U.M. 17941, ×1. (p. 565)

lapped by the inner socket ridges. The hinge plates extend nearly horizontal continuous with the inner socket ridges. The dental lamellae are short and divergent.

"Cyclothyris" subtrigonalis is represented by 10 distorted specimens in which the features of the beak region are poorly preserved. An associated species, represented by three specimens, has four costae in the sinus and five costae on the fold.

Holotype, U.M. 18748; paratypes, U.M. 18747, 18749, 17948, Museum of Paleontology, University of Michigan.

Occurrence.—Near base of Cretaceous section at reservoir locality at northeast limit of Miquihuana, Tamaulipas.

Genus TEREBRATULA MÜLLER, 1776 (sensu lato)

"TEREBRATULA" SILLIMANI Imlay, n. sp.

Plate 83, figures 1–5; text figure 8

Shell subcircular in outline, both valves moderately convex. Brachial valve with a low median fold, which begins about 16 mm. from the umbo; pedicle valve with corresponding median flattening. Anterior commissure uniplicate. Lateral commissure inclined slightly ventrally. Umbo erect, projecting beyond brachial valve. Foramen circular. Permes-

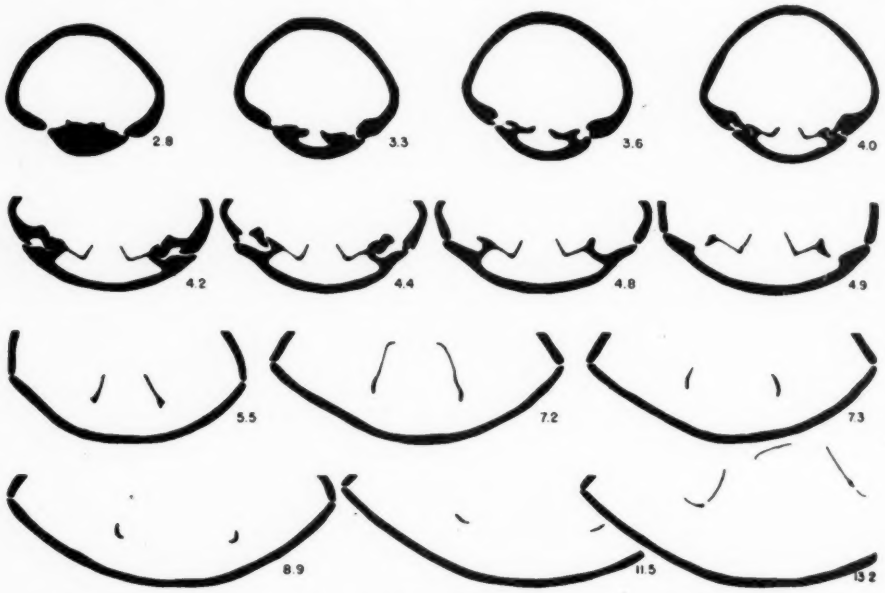


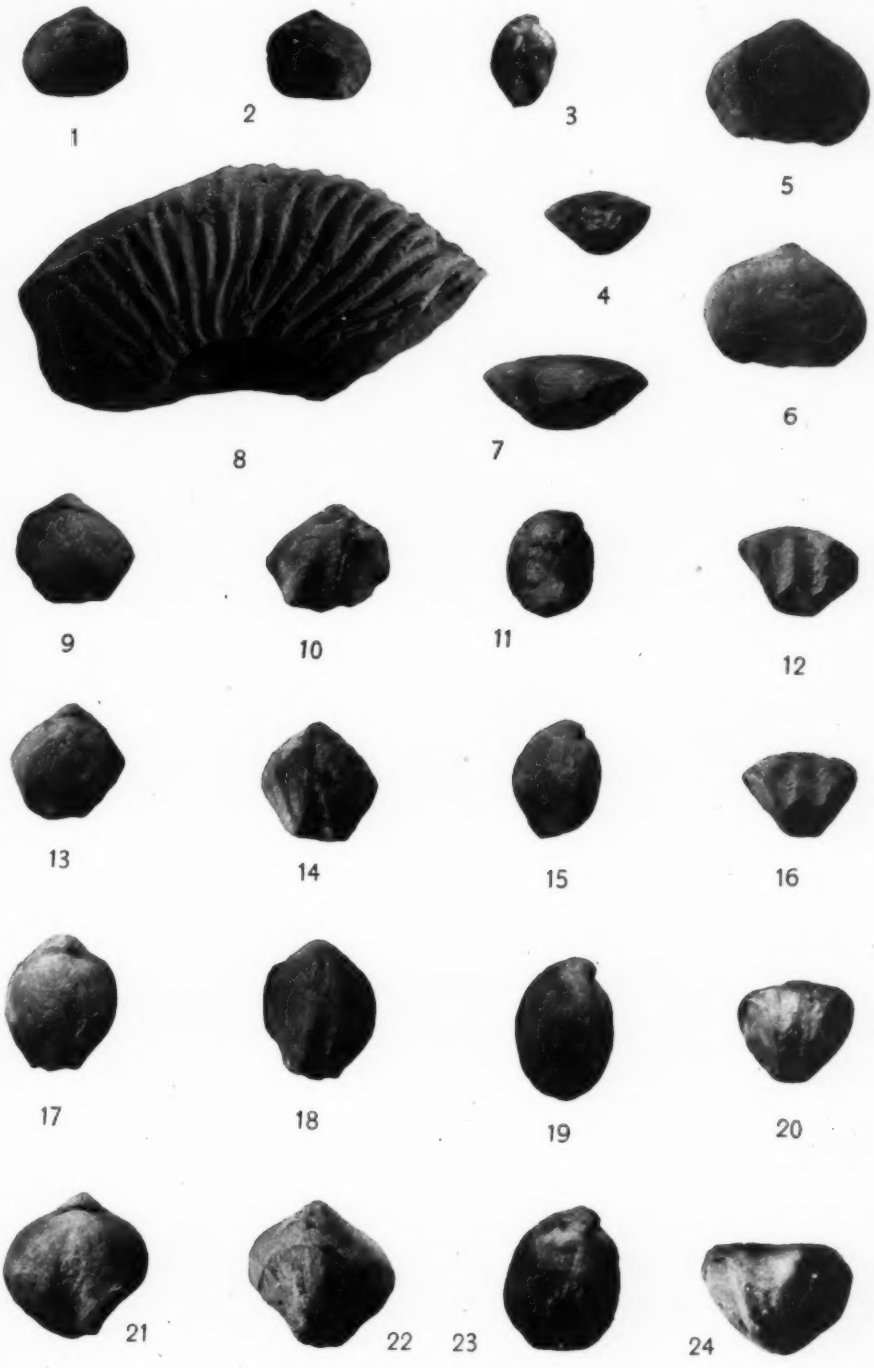
FIG. 8—Transverse sections of *"Terebratula" sillimani* Imlay. Length of shell, 29.5 mm. Distance of sections from beak of pedicle valve in millimeters. ×2.

EXPLANATION OF PLATE 82

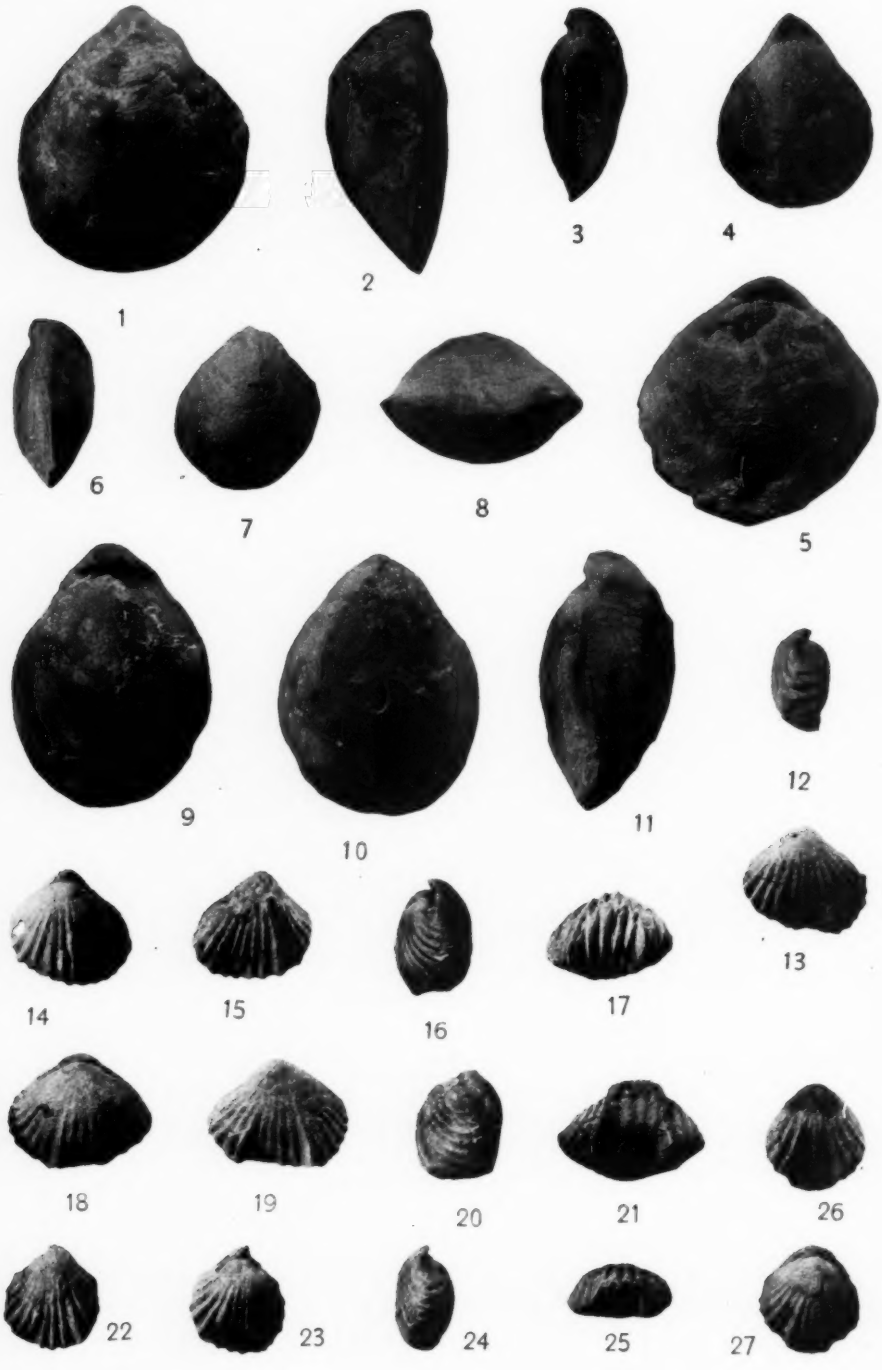
FIGS. *1–7—Antiptychina? lata* Imlay, n. sp. *1–4*, Dorsal, ventral, lateral, and anterior views of holotype, U.M. 18739; *5–7*, ventral, dorsal and anterior views of paratype, U.M. 18740; ×1. (p. 569)

8—Thurmannites angusticostatus Imlay, n. sp. Paratype, U.M. 18608, ×1. (p. 562)

9–24—Antiptychina? müllerriedi Imlay, n. sp. *9–12*, Dorsal, ventral, lateral, and anterior views of paratype, U.M. 18742; *13–16*, same views of holotype, U.M. 18752; *17–20*, same views of paratype, U.M. 18745; *21–24*, same views of paratype, U.M. 18744; ×1. (p. 568)



Imlay, Neocomian Fossils from Mexico



Imlay, Neocomian Brachiopods from Mexico

othyrid. Beak ridges subangular. Holotype 25.3 mm. long, 20.8 mm. wide, and 11.7 mm. thick.

Hinge plates separated from inner socket ridges by a sulcus. Sockets deep and narrow; overlapped by inner socket ridges, which articulate with a sulcus in the inner margin of the teeth. The crural bases are given off ventrally and in the anterior sections project almost at right angles to the hinge plates. A slight projection from the outer socket ridges fits into the denticular cavity, and the denticula fit into an accessory socket in the outer socket ridges. The loop is about 11 mm. in length in a brachial valve about 27.2 mm. in length.

This species is very common in the basal Cretaceous beds at Miquihuana. Compared with *"Terebratula" tamaulipana* Imlay the shell is rounder in outline, the anterior commissure less strongly uniplicate, and the brachial valve a little less convex.

Holotype, U.M. 18751; paratypes, U.M. 18750, 18741, 18655, Museum of Paleontology, University of Michigan.

Occurrence.—(1) Collections 2, 3, and 4 of unit 3 of section 1 mile east of Miquihuana; (2) near base of Cretaceous section at reservoir locality at northeast limit of Miquihuana.

"TEREBRATULA" TAMAULIPANA
Imlay, n. sp.
Plate 83, figures 6–11

Shell subovate in outline, both valves moderately convex. Brachial valve with a low median fold, which begins about 21 mm. from the umbo; pedicle valve with corresponding median flattening. Anterior commissure uniplicate. Lateral commissure inclined slightly ventrally, then recurving slightly near the anterior margin. Umbo erect, projecting slightly beyond brachial valve. Foramen circular. Permesothyrid. Beak ridges subangular. Holotype 34.5 mm. long, 27 mm. wide, and 17.7 mm. thick.

The internal characters are similar to those of *"Terebratula" sillimani* Imlay.

Holotype, U.M. 18743; paratypes, U.M. 18753, 18656, Museum of Paleontology, University of Michigan.

Occurrence.—Collection 1 from unit 2, and collections 2, 3, and 4 from unit 3 of section 1 mile east of Miquihuana, Tamaulipas.

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EXPLANATION OF PLATE 83

FIGS. *1–5*—*"Terebratula" sillimani* Imlay, n. sp. *1, 2*, Ventral and lateral views of paratype, U.M. 18741; *3, 4*, lateral and dorsal views of holotype, U.M. 18751; *5*, dorsal view of paratype, U.M. 18750; ×1. (p. 572)

6–11—*"Terebratula" tamaulipana* Imlay, n. sp. *6, 7*, Lateral and ventral views of paratype, U.M. 18753; *8–11*, anterior, dorsal, ventral, and lateral views of holotype, U.M. 18743; ×1. (p. 573)

12, 13, 22–27—*Cyclothyris? subtrigonalis* Imlay, n. sp. *12, 13*, Lateral and dorsal views of paratype, U.M. 18747; *22–25*, ventral, dorsal, lateral, and anterior views of paratype, 18749; *26–27*, ventral and dorsal views of holotype, U.M. 18748; ×1. (p. 571)

14–21—*"Rhynchonella" miquihuanensis* Imlay, n. sp. *14–17*, Dorsal, ventral, lateral, and anterior views of holotype, U.M. 18738; *18–21*, same views of paratype, U.M. 18746; ×1. (p. 570)

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NOTE: The manuscript of this paper was received by the editor July 7, 1937.

JOURNAL OF PALEONTOLOGY, VOL. 11, NO. 7, PP. 575–597, 1 TEXT FIG., OCTOBER, 1937

SYSTEMATIC POSITION OF THE OLENELLIDAE (MESONACIDAE)

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ABSTRACT

The Olenellidae, a family of trilobites characteristic of the Lower Cambrian, present a striking mixture of primitive features and specialized features such as the lack of a facial suture as a parting across the cheek, the rearward course of the trace of the anterior branch of the suture, the crescentic form of the rostrum, and the continuous submarginal suture. These specialized features are related to the metaparial head plan characteristic of the Olenellidae as distinguished from mesoparial and proparial trilobites.

These three types differ most conspicuously in having respectively developed different pairs of primitive spines to form the genal spines. Proparial trilobites developed the posterior pair of cephalic spines borne at the posterior angles of the cranidium (metacranidial spines) as genal spines in their primitive position. Mesoparial trilobites rotated the parial spines, borne primitively at the sides of the free cheeks (pareiae), to the rear to form their genal spines. Metaparial trilobites rotated the procranidial spines, borne primitively at the anterior angles of the cranidium, to the posterolateral angles of the cephalon to form the genal spines. In most cases the other pairs of spines aborted.

The revolution of the spines from the front to the rear was accompanied by a stretching out to the genal angles of the anterior margin, of the rostrum beneath it, and of the rostral suture between these. The spines carried with them also the anterior branches of the facial sutures, and the continuations of these across the doublure—the connecting sutures—to the genal angles. This rearward revolution on each side had three primary effects, a secondary, and a tertiary effect on the sutures: the dorsal facial suture became triangular in plan, and hence inefficient for ecdysis; the rostral suture became semicircular; the connecting sutures, originally very short, apparently shortened to disappearance, leaving as the marginal suture the rostral suture alone, cutting the inner edge of the doublure. The dorsal facial suture had thus become quite inefficient for ecdysis, at the same time that the ventral sutures, as the marginal suture, had taken on almost the most efficient form possible, alone quite sufficient for ecdysis. Consequently as a secondary effect, the combined dorsal and ventral sutures were superseded for ecdysis by the marginal suture acting alone; and as tertiary effect, the dorsal facial sutures later underwent ankylosis through disuse.

Thus this revolution of the cheeks, which is strongly indicated by the ontogenies of olenellids, explains all the special characteristics of the family. The cause of this remarkable revolution is believed to be the very early adoption of a shallow burrowing mode of life, for which the body-form in most of the genera is well adapted.

The various trilobite species that had previously been referred to *Olenellus* and its subgenera were by Walcott (1891, p. 635) erected into the family "Mesonacidae," distinguished from Paradoxidae by the absence of the facial suture. Walcott avoided the obviously most suitable name of Olenellidae "on account of its similarity to Olenidae" (1891, p. 635). But the argument did not appeal to others; both Vogdes (1893, p. 254) and Moberg (1899, p. 310, f.n.), though aware of Walcott's term, used the name Olenellidae.

Olenellus ("*Mesonacis*") *vermontana* (Hall), after which the family was named, is of special interest because it showed for the first time that the supposed terminal tail spine of *Olenellus* had originated by the development of the dorsal spine of a normal, and far from terminal, segment—the fifteenth postcephalic—

suggesting at the same time a like origin for the corresponding features in *Limulus*, eurypterids and scorpions. Walcott's name depended on the supposed generic distinctness of the species *Olenellus vermontana*, which constituted his genotype of *Mesonacis*, from *Olenellus thompsoni* (Hall). Walcott believed that in the latter the body terminated behind in the tail spine on the fifteenth postcephalic segment, which segment in *O. vermontana* was known to be followed by 10 reduced segments and a pygidium. Resser (1928, pp. 3–5) showed that this distinction breaks down: that *O. thompsoni*, also, had reduced segments and a pygidium behind postcephalic segment 15. The present writer (Raw, 1936, pp. 242–243) argued that *Mesonacis vermontana* should revert to *Olenellus*. Subsequently both Resser and J. F. Mason in private communications have pointed out that the family name Mesonacidae is now invalid and should be changed to Olenellidae, which indeed should never have been passed over.

The family holds a noteworthy and, indeed, a unique position. In the oldest marine rock series known, the Lower Cambrian, in which these trilobites occur, they are much the largest trilobites, thus occupying a similar place in these to that of the Paradoxidae in the Middle Cambrian. Like the Paradoxidae so far as known they are limited to the Northern Hemisphere. And, though many other families of trilobites occur in the Lower Cambrian, none characterize it as do the members of this family: it ranges indeed through the series almost from the basal unconformity to the summit, and is never associated with *Paradoxides*.

Structurally, too, the family is unique among trilobites in several ways, especially in that all members, though possessing large compound eyes, are without the facial sutures, which in other families separate the free cheeks, bearing the eyes, from the cranidium. Several observers besides Ford (1877, p. 271) have noted that the cheeks fracture as easily in one direction as another.

As it is one of the very oldest of our trilobite families, and is structurally unique, it is not surprising that the ontogenies, structures, and phylogenetic relationships of the Olenellidae should present problems of great interest. In 1925 and in 1927 I interpreted anew the known ontogeny and structure within the family. Many contrary views have since been expressed, to which I have not replied. Recently I have described the Mesonacidae of Comley in Shropshire (England), and discussed the classification within the family (Raw, 1936 a and b). This study has furnished further evidence of structural features bearing on the systematic position of the family, which fully supports and also extends my previous conclusions. I take this occasion to review the subject and to answer the objections that have been raised. Direct criticism has in no case come from researchers on the group, who seem to have been unaware of my views.

CHARACTERISTICS AND SUBDIVISIONS OF THE OLENELLIDAE

As the cephalon is the most specialized part in trilobites, it is mainly by its characters that the systematic position is to be adjudged; but the characters of the postcephalic body are also of significance —indeed of much greater significance than can be explained in this paper.

Compared with other trilobites, olenellids present a most interesting association of primitive and specialized characters. A characterization of the family "Mesonacidae" is given by Walcott (1910, p. 236). My own diagnosis is as follows (Raw, 1936 b, pp. 239, 240):

Entire form: semiovoid or more elongate.

Cephalon: large; in the larva often with three pairs of cheek spines; in the adult always with one pair persisting as the genal spines, sometimes with a second smaller pair persisting as intergenal spines.

Facial sutures: vestigial (in a condition of symphysis); when traceable, metaparial, i.e., the anterior branch bends round towards the genal spines.

Axial lobe: long and prominent, with long "frontal" lobe.

Eyes: crescentic, with the palpebral lobes more or less continuous with the frontal lobe of the glabella.

Rostrum: crescentic, underlying the border, and reaching, where known, nearly to the genal angles; separated from the dorsal shield by a suture, which in front is marginal but laterally crosses the doublure to cut its inner margin at or near the genal angles; continuous with the front of the hypostoma through obsolescence of the hypostomal suture.

Hypostoma: large, with semiovoid main body, and more or less spinose posterolateral margins.

Thorax: large, of a variable number of segments, usually 18 or fewer, but sometimes much more numerous. Third segment sometimes macropleural. Axial spines typically retained in some part.

Pygidium: minute; undivided or with very few segments indicated.

Test very thin. Sculpture: usually a network of raised lines, sometimes accompanied by granules in the meshes, or granules may occur alone.

In the same paper (Raw, 1936 b, p. 244) I subdivided the family into three clans, as follows:

1. *Olenellus* group: with *multidentate hypostome* (6 teeth each side), usually with third thoracic segment macropleural, and with specialization of posterior thoracic axial spine or spines and loss of these in front, and genal spine consisting of the procranidial alone (Raw, 1925, p. 307 et ante).
   "*Mesonacis*," *Olenellus*, *Wanneria*: *Paedeumias*: *Elliptocephala*: *Olenelloides*.
2. *Holmia* group: with *paucidentate hypostome* (2 teeth each side), with evenly developed pleura, with vestiges of anterior and posterior branches of facial suture as well as of the occipital anterior pleural ridge, and genal spine due to coalescence of procranidial and parial spines (Raw, 1925, p. 295).
   Holmia, *Kjerulfia*: ("*Schmidtiellus*" = *Holmia*) (Schindewolf, 1927, pp. 115, 117), *Callavia*, *Cobboldus* (Raw, 1936 b, p. 261).
3. *Nevadia* group: with *glabella narrowing to*

the front, with wide cheeks and pleural lobes of thorax. Hypostome perhaps smooth-bordered.

Nevadia, *Nevadella* (Raw, 1936 b, p. 250).

INTERPRETATION OF THE FAMILY CHARACTERISTICS

The assignment of systematic position depends on our interpretation of the family characters. Which characters are primitive and which specialized is a matter of opinion; but for myself, after a very close study of the group, I am now in no doubt.

Primitive features.—Primitive features characterizing most members of the family include the excessive thinness of the test; the great number of segments; the presence of axial spines, the preservation of segmentation both on the cephalic axial lobe and, in early stages of development, on the intraocular cheeks; the minute pygidium, exhibiting usually only a single segment; the long eyes; the presence in young stages of three pairs of cephalic spines, and the retention by the adult, in some forms, of two of these pairs.

Specialized features.—Specialized features characterizing all members of the family include effective coalescence of two segments in the frontal lobe of the glabella (this is a specialization relative to the ancestral annelid; in most families of trilobites specialization in this direction has gone much farther); absence of facial sutures as partings across the cephalon, their representation being by faint lines only—especially seen on internal moulds; the remarkable rearward course of the anterior branch of the "suture," when visible; and the remarkable triangular course of the whole "suture" line; the long crescentic form of the rostrum (rostral plate); the continuous semicircular course of the marginal suture forming the outer boundary of the rostrum; and the absence of the hypostomal suture (shared with most *Paradoxides*—Westergård, 1936, pp. 33, 38, 42, gives the known exceptions).

Frequent also in the family is the special development of particular median spines (the *Olenellus* group and *Callavia*); so also is the great variation in the size of the thoracic pleura. This, however, is a development of primitive differences.

A brief discussion may here be given of these features, and more especially of those of which differing interpretations have been offered.

NOTES ON PRIMITIVE FEATURES

Thin test.—Compared with other trilobites, and indeed, compared with other Lower Cambrian trilobites, the olenellid shell is for its size excessively thin. In the Comley (Shropshire) sandstones it is much thinner than at first appears; in these

the apparent shells of *Callavia* fragments are very thin; and these as seen in rock sections are quite four times as thick as the actual shell, having been thickened on both sides before entombment by a mineral deposit of more coarsely crystalline calcite one and a half times to twice as thick as the original test (Raw, 1936 b, p. 257).

Numerous segments.—The rich segmentation will be accepted by most zoologists as a primitive character.

Except in the aberrant *Olenelloides* the number of free segments is always large. There are usually 18 free segments—*Olenellus*, *Paedeumias*, *Wanneria*, *Elliptocephala*, *Kjerulfia*, *Callavia*. In *Olenellus* there are 14 in front of the great spine, and in *O. thompsoni* there are three behind (Resser, 1928, p. 4). There may, however, be many more than 18, e.g., *Nevadia weeksi* Walcott, *Olenellus* (*"Mesonacis"*) *vermontana* (Hall), *Olenellus* (*"Paedeumias"*) *robsonensis*.

Axial spines.—In the *Holmia* group (*Holmia*, *Kjerulfia*, *Callavia*, *"Schmidtiellus"*) practically all the free segments retain axial spines, a feature that I regard as primitive and inherited from the proarthropod. In *Elliptocephala* also most segments retain axial spines.

Segmentation of cephalon.—All the Olenellidae exhibit very clear segmentation in the axial lobe. In front of the occipital ring, always very clearly defined by occipital furrows, we have three glabellar lobes comparable with the occipital, and a large frontal lobe. In early stages of development the rings behind the frontal lobe are closely comparable with those of the thorax and sometimes even retain vestiges of their axial spines (*"Paedeumias transitans,"* from Helena, Alabama). The frontal lobe in this family retains only faint traces of a composition of two segments—by faint lateral furrows, seen in *Elliptocephala asaphoides* (Walcott, 1891, pls. 89 and 90) and *Callavia* (Walcott, 1891, pl. 91; Raw, 1936 b, pl. 16, figs. 1a, 1b, 2a, 4b). Some other trilobites indicate more clearly the presence of two segments in the frontal lobe, e.g., members of the Zacanthoidae, Paradoxidae, Encrinuridae, and Phacopidae. Some of these strongly suggest that it consists of two segments only, e.g., the unswollen glabellae of Zacanthoidae and Encrinuridae. Very strong indications of this are furnished by larval stages of the Zacanthoidae, e.g., *Albertella bosworthi* Walcott with head length of 1.4 mm., exhibiting in the axial lobe six subequal segments separated by simple transverse furrows.

But larval Olenellids have simple segmentation, not only in the axial lobe behind the frontal lobe but also in the intraocular cheeks. The explanation of this may be, that since they are large trilobites, earlier stages of development are preserved than in other Lower Cambrian trilobites; since they are also among the earliest trilobites, their development recalls even the origin of the Arthropod head by coalescence of pleura as well as of axial rings.

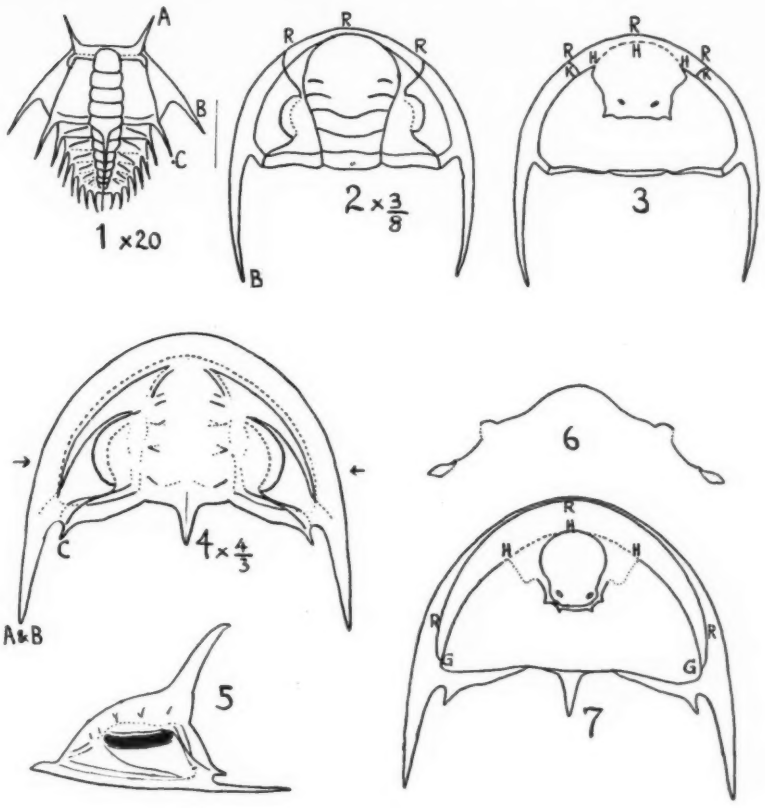
Walcott was the first to figure and describe this segmentation, viz., in *Elliptocephala asaphoides* (Walcott, 1886, p. 169; pl. 17, figs. 5 and 6). Later he figured it without comment in several other forms, viz., *"Paedeumias transitans"* Walcott, of Helena, Shelby County, Alabama; *Olenellus gilberti* (Meek); *Olenellus lapworthi* Peach; *Nevadella* (*"Wanneria?"*) *gracile* (Walcott), (Walcott, 1910, pl. 25, figs. 21, 22; pl. 36, figs. 12, 14; pl. 39, fig. 6; pl. 38, fig. 24).

Kiaer figured and described the best example, viz., in *Holmia kjerulfi*

(Linnarsson) (Kiaer, 1916, p. 66, fig. 11a, p. 67; pl. 6, fig. 1); and Poulsen figured and recorded similar segmentation in *Paedeumias hanseni* Poulsen (Poulsen, 1932, p. 45; pl. 2, figs. 5, 6, 7).

So many forms exhibit it that it is probably universal within the family. Usually the intraocular cheek is traversed by three grooves or ridges or both, directed outwards and backwards from the occipital furrow and from the two posterior glabellar furrows. The last pair of ridges is the strongest and is continued to form the inner boundary of the intergenal spines. The regularity of these features and their exact correspondence with the segmentation of the axial lobe precludes any interpretation except that of a segmentation of the intraocular cheeks. Both Walcott and Kiaer interpret them in the same particular way: namely, as *intersegmental* divisions, i.e., between pleura of the cephalic segments; and they each attribute the intergenal spine to the *last glabellar segment.* Stubblefield also supports this view and even claims that the intergenal spine of Olenellids is not homologous with the intergenal spine of *Paradoxides* ("*Hydrocephalus*") and the genal spine of proparial trilobites (1936 a, p. 68; 1936 b, pp. 425, 426). This view I have controverted (Raw, 1925, pp. 288–289; Raw, 1936 a, pp. 68, 69; or Raw, 1936b, pp. 292, 293). What would survive when the cephalic pleura of the proarthropod coalesced into the cheek of the arthropod can be judged from what survived when the pygidial pleura coalesced into a pygidium. Comparison of thorax and pygidium in ordinary trilobites shows that what have survived the coalescence of segments in a pygidium are not the intersegmental divisions but the oblique pleural ridges and furrows: doubtless because these had a close relation to the muscles. So it is on the cephalon: the lines across the intraocular cheeks are survivals not of the intersegmental divisions but of the pleural ridges and furrows; and they cross the segments obliquely, as in the thorax. The posterior pair are the strongest, because they alone have muscular connection with a movable segment, the first thoracic, and they alone are associated with a free pleural boundary—the posterior margin of the cheeks. This last pair persists to the adult in *Holmia kjerulfi* and *Kjerulfia lata;* and throughout development they bear such close comparison with the pleural ridges and pleural furrows on the adjoining thorax as to indicate that it is the pleural ridge and furrow of the occipital segment and that the intergenal spine is the pleural spine of the same segment and not of a glabella segment as others claim (Walcott, 1910, p. 238; Kiaer, 1916, p. 66; Stubblefield, 1936 b, pp. 425, 426).

Minute pygidium.—The minute pygidium usually met with in the family, exhibiting often only a single segment, suggests the telsonic segment of annelids and will be accepted by zoologists as a primitive feature. In *Holmia*, however, the pygidium suggests a composition of three seg-



FIGS. 1–7—Outline sketches of trilobite cephala to illustrate and to compare with the structure of *Callavia*, an olenellid.

1—Heptacicephalic larva of the olenid *Leptoplastus salteri* (Callaway) in early meraspid stage, degree 1, ×20. All three pairs of primitive cephalic spines—A, procranidial; B, parial; C, metacranidial—are in their primitive positions.

2—*Paradoxides spinosus* Boeck, dorsum, after Barrande, ×⅜. Only the parial spines (B) survive.

3—The same, ventrum; to show the rostrum, bounded by the rostral suture RR and the connecting sutures K, but coalesced behind with the hypostome through ankylosis along the hypostomal suture HH.

4—*Callavia callavei* (Lapworth), dorsum, ×⅔. The intramarginal furrow is dotted; the continuous line within this is the intramarginal ridge. The crescentic eyes are indicated by continuous lines, from the two ends of which run the vestiges respectively of the anterior and of the posterior branches of the facial suture, the latter tangential to the anterior occipital pleural ridge (intergenal ridge). The hypothetical extensions of the sutures across the border are dotted.

5—The same, in side view.

6—The same, in cross section between the arrows of fig. 4.

7—The same, from below, to illustrate the ventral sutures. GRRG, marginal or rostral suture. GHHG, the inner border of the rostrum, coinciding in position with the inner edge of the dorsal border. HHH, the hypostomal suture in ankylosis. The hypostome is represented foreshortened; its wings are hypothetical.

Fig. 1 has been traced from *Am. Jour. Sci.*, vol. 14, 1927, p. 24, fig. 6; figs. 2 and 3 have been redrawn from *Geol. Soc. London, Quart. Jour.*, 1925, pl. 15, figs. 4 and 4a; figs. 4, 5, and 6 are reproduced by permission from *Geol. Soc. London, Quart. Jour.*, 1936, p. 247, figs. 1a–c.

ments, in harmony with its thorax of 16 segments only.

Long eyes.—The eyes have been proved by Walcott and Kiaer to be normal compound eyes. Walcott compared them with those of *Limulus* (Walcott, 1910, p. 239, pl. 43; Kiaer, 1916, p. 64). That long eyes in trilobites are primitive is generally accepted. In several families both the geologic succession of related forms and successive stages in the ontogenies exhibit a shortening of the eye. Both Olenellidae and Paradoxidae abundantly exhibit this.

Primitive nature of paired spines and facial sutures in trilobites.—The claim I made in 1925 and 1927 and still make, that three pairs of cephalic spines and also the dorsal facial sutures are morphologic entities and are primitive in trilobites, has not met with general acceptance. This may be because I have not yet presented the full evidence, and because hitherto only a single olenid—*Leptoplastus salteri*—and certain Olenellidae have exhibited all three pairs of spines. The *Leptoplastus* shows them because the specimens are flattened in shale and the tests dissolved out by weathering, thus causing the shale partings to extend along them and disclose them (fig. 1).

That both these sets of features are morphological entities is suggested by the fixed relationship between them. The anterior and posterior pairs of spines are borne by the cranidium at its anterolateral and posterolateral boundaries respectively, and there is reason to interpret them as the pleural spines of the foremost and the hindmost dorsal segments of the head. I called them the procranidial and metacranidial spines. The middle pair are borne on the free cheeks or pareiae and were called the parial spines. There is reason to believe that each of these is due to coalescence of the pleural spines of the third and fourth dorsal segments.

Primitive paired spines of Olenellid cephalon and their specialized disposition.—Although the presence of three pairs of spines on the cephalon is a primitive feature, their peculiar disposition in the Olenellidae is a specialization with which are closely connected the most distinctive features of the family. It will be best to take all these together. These distinctive features are the lack of facial sutures, and their representation by faint lines; the course of the anterior branch to the genal angle and the somewhat triangular course of the whole "suture"; and the extension of the rostrum and of the rostral sutures to the genal angles.

Among olenellids three pairs of cheek spines are present in *Olenelloides armatus* Peach; and in early stages of *Olenellus* (*"Mesonacis"*) *gilberti* (Meek), *Elliptocephala asaphoides* Emmons, *Paedeumias transitans* Walcott of loc. 8q, northwest of York, Pennsylvania, and *"Paedeumias transitans"* Walcott, a different species, from Helena, Shelby County, Alabama. It is therefore not improbable that all three pairs of head spines may have existed in young stages throughout the family. Never more than three pairs occur in any

trilobite ontogenies, and we are therefore justified in seeking to homologize them with the three pairs of *Leptoplastus*. The sutures, however, in the above-mentioned species are represented by vestiges of the posterior branches only; so that, of the cranidial spines, only the metacranidial can be observed in relation to an adjoining suture—the posterior branch.

Also, though in *Olenelloides* and the larvae of *Olenellus gilberti* the three pairs of spines occupy the presumably primitive position of those of *Leptoplastus*, in *Elliptocephala* and in the *Paedeumias* species they show themselves only on or near the posterior border. The three pairs of spines of *Elliptocephala* were first observed by Ford when he described the development. The series of stages was extended by Walcott. In the youngest stage, first described by Walcott, only the metacranidial spines appear. At a later stage, the youngest known to Ford, the parial and the metacranidial adjoin one another on either side of the vestige of the posterior branch of the suture, i.e., the parial had already revolved to the rear either in development or in evolution. In the next stage, in the place of the two spines we have a single spine, the intergenal spine; and another spine appears at the posterolateral angles of the shield, and this also in later stages revolves rearward. This spine I interpret as the procranidial and believe that the intergenal spine is the completely coalesced metacranidial and parial.

Ford, however, expecting only two pairs of spines, intergenal and genal (metacranidial and parial), believed that they had come together and then separated again; in which case there would have been a reversal of development.

That the new spine is the procranidial is suggested by its subsequent further revolution to the rear; and that the intergenal spine is the completely coalesced metacranidial and parial is supported by the development of the "*Paedeumias*" from Helena, Alabama, above mentioned, where the stages into complete coalescence can be traced, and the third spine, the procranidial, has already appeared.

The development of the *Paedeumias transitans* from York, Pennsylvania, which at that time I thought was identical with *Olenellus thompsoni*, I discussed and interpreted in 1927. I saw no evidence of coalescence of spines and believed that they remained distinct from one another on the posterior border. Whether they remain thus distinct should be determined by a restudy of the material.

The forms here above discussed all belong to the *Olenellus* group. Another condition of things is met with in the *Holmia* group. Here material is very scanty; besides the adults of various species, some well preserved, we have little besides what is furnished by Kiaer, namely a protaspis and a few later stages of *Holmia kjerulfi*. The protaspis exhibits the metacranidial spines, which persist as the intergenal spines of the adult. Only one other pair of

spines appears in later development —the genal spines. As is shown below, the course of the anterior branch of the facial suture, the shape of the rostrum, and the course of the marginal suture, all indicate that the procranidial spines have revolved round to the genal angle. And as the intergenal spine is the metacranidial alone, it is probable that the genal spine here is the parial and procranidial coalesced (fig. 4). This genal spine, which first appears at the midlength of the shield, later, as in other cases, moves rearward.

In *Nevadia* or other members of the *Nevadia* group, the evidence is insufficient to indicate the condition. *Nevadia weeksi* exhibits an intergenal angle and a genal spine; and in one cheek of this species figured by Walcott (1910, pl. 23, fig. 6), a faint line can be traced obliquely across the vascular markings, extending part of the way between the front of the eye and the genal angle. If this line is a vestige of the anterior branch of the suture, as its position suggests, it indicates revolution of the suture, and so of the procranidial spine, to the genal angle.

Typical olenellids have a semicircular cephalon with one or two pairs of spines persisting, limited to the posterior border. From the structure and ontogenies there is reason to believe that in all typical forms, the procranidial spines are in place at the genal angle and therefore that the loci of all the paired head spines are congregated on the short posterior borders. Under such conditions it is not surprising that we should see evidence of coalescence of two spines into one. This type of head plan, viz., with the procranidials at the genal angles, I have called *metaparial*. But if the procranidials have revolved to the genal angles, as is indicated by the ontogenies, they could not go alone. Their primitive relation to the anterior branches of the facial suture and to the connecting sutures would inevitably carry the anterior branches of the facial sutures and probably also the connecting sutures to the genal angles, too. Indeed it might involve, as I believe it did, all the lateral organs of the head.

NOTES ON OTHER SPECIALIZED FEATURES

Representation of the facial suture: the rearward course of the anterior branch, and the triangular course of the whole "suture" (figs. 4, 5, and 7).— Although no dorsal facial suture as a line of parting is present in the family, lines exist with courses so closely comparable to those of the facial suture of *Paradoxides*, for example, that one must regard them as representing such dorsal sutures.

Members of the *Olenellus* branch of the family, a relatively specialized branch to which belong the forms early studied by Walcott, exhibit traces only of the posterior branch of the suture—a sigmoid line running rearward and then outward from the posterior end of the eye, in quite a normal course. In these this is the only line here.

The anterior branch of the suture was first recognized by Moberg in his *Holmia* or *Kjerulfia lundgreni*

and in *Holmia kjerulfi*, running from the front of the eye and curving round towards the genal angle. Kiaer recognized it also in his *Kjerulfia lata*. In *Callavia* it is easily seen, and is abundantly illustrated in Raw, 1936 b. The posterior branch also in these forms is visible in addition to the intergenal ridge discussed above. But whereas in *Holmia* and *Kjerulfia* the posterior branch of the "suture" is entirely in front of and quite distinct from the intergenal ridge, in *Callavia* the two features coalesce in the middle part of their courses, showing *Callavia* to be the more specialized (see fig. 4) (Raw, 1936 b, pp. 248, 254, 262, 263).

The course of the posterior branch is quite normal—closely comparable with that of *Paradoxides;* but that of the anterior branch is unique in being directed to the genal angle, and so has not been generally accepted as such, though such a course is approached in *Paradoxides rugulosus* (Kiaer, 1916). But if the *Holmia* group agrees with *Elliptocephala* and *Paedeumias* in having the procranidial spine at the genal angle, this would furnish a complete explanation. The procranidial spine must have reached the genal angle by revolution, and this would necessarily involve also revolution of the anterior branch of the suture in advance of it. That this took place is proved by the features of the ventral side of the cephalon.

The whole course of this suture—(1) from within the genal angle, along the anterior branch to the anterior end of the eye, (2) along the crescentic eye, and (3) from the posterior end of the eye, along the posterior branch to beyond the locus of the intergenal spine—is roughly triangular, but open at the genal angle (fig. 4). It is found in no other family of trilobites and is the farthest removed from the relatively straight course from front to back seen in the most primitive trilobites.

Neither the posterior nor the anterior branches can, as a rule, be traced across the border, but, as the "suture" is not functional as a line of parting, this is not surprising in view of the specialization that has affected the border.

Long crescentic rostrum and semicircular marginal suture (contrast figs. 3 and 7).—On the ventral side, the hypostome, especially in the *Holmia* group, is very closely similar to that of *Paradoxides;* and in all known olenellids and in most paradoxidids it has coalesced with the rostrum, ankylosis having presumably taken place along the hypostomal suture. The similarity of form is best attributed to common inheritance but, in view of the fact that the earliest *Paradoxides* had not undergone the usual ankylosis of the hypostomal suture, we can attribute this latter only to a similar mode of life, which is strongly indicated in other ways.

On the other hand the form of the rostrum is markedly contrasted in these two families. In *Paradoxides* it forms only the anterior part of the doublure, being bounded at the sides by the connecting sutures (ventral continuations across the doublure of the anterior branches of the facial

suture), and round the front by the rostral suture, of the same length as the rostrum. These two sutures meet one another at an angle (Barrande, 1852, pl. 2b, fig. 3, etc. . . . Westergård, 1936, pl. 6, fig. 15).

In the Olenellidae, wherever the rostrum is known it is long and crescentic and constitutes most of the doublure right to the genal angles (fig. 7). It is bounded outside by a suture—the marginal suture—which is semicircular and curves inward at the ends to cut the inner edge of the doublure. This bounding suture we can compare and homologize with the bounding sutures of the rostrum of *Paradoxides*, viz., the rostral and connecting sutures. This crescentic rostrum with the marginal suture bounding it, suggests by its form a stretching of the primitive anterolateral boundaries round to the genal angle. The marginal suture is, however, a continuous curve, and therefore the stretching out of the rostrum may have been accompanied by a continuous abbreviation of the short connecting suture till the rostral suture came to cut the inner edge of the doublure.

In the ontogenies of *Elliptocephala asaphoides* and two species of *Paedeumias* the successive appearances of the paired spines on or near the posterior border, and their subsequent changes, coalescence and migration, indicate that in these forms the procranidial of the adult occupies the genal angle (p. 583). Again in the members of the *Holmia* group the position of the line representing the anterior branch of the suture indicates that in these forms also the procranidial spine must be at the genal angle. The form of the rostrum and of the marginal suture strongly supports these conclusions. Indeed only in this way can they be explained.

Ankylosis along the facial sutures.—If no trace existed of the facial sutures, one might believe with Walcott, Swinnerton, Poulsen, and Stubblefield that they had never existed. But as the course of the posterior branch is often visible in all groups, and the courses of both the anterior and the posterior are clearly traceable in the members of the *Holmia* group, it is much more reasonable to suppose that ankylosis has occurred along them. Indeed this is the only reasonable theory; because such ankylosis would be the inevitable result of the disposition of the sutures, dorsal and ventral, which has above been shown to exist. In the heptacicephalic ancestor of the Olenellidae each facial suture would have a fairly straight course from front to rear across the cheek. With widening of the cheeks the course would become more indented. But on the revolution of the procranidial spines and the adjoining outer parts of the anterior branches of the suture to the genal angles, each suture line became triangular, as is still clearly visible in the *Holmia* group. Such a course was very inefficient for ecdysis; but the rostral suture with the connecting sutures, having been in the same process stretched out into a great semicircle extending from one genal angle to

the other—the marginal suture—had acquired almost the best possible form for ecdysis. It was natural, therefore, that the dorsal and ventral sutures, which in the ancestor acted together as the ecdysial line, should be superseded in the olenellid by the marginal (ventral) suture acting alone. The dorsal facial sutures consequently ankylosed through disuse. I cannot agree with Stubblefield's view that the sutures served other purposes besides ecdysis. (See Stubblefield, 1936 b, pp. 408–414 and 437.)

All these specializations so far considered appear to be closely connected, and the one of greatest importance, that which appears to carry the others with it as effects, is the presence of the procranidial spines at the genal angles, constituting the metaparial head plan. The origin of this involved (1) the stretching out of the short primitive anterior margin into a semicircle extending to the genal angle, and (2) the addition of the primitive lateral margin with its parial spine to the posterior margin, to constitute that margin outside the metacranidial spine. Though the posterior margin of the olenellid is probably much longer in proportion than that of its primitive ancestor, this addition to it involved much contraction of the border of each pareia, with crowding together of the spines. In short, the revolution involved great stretching of the primitive anterior and much contraction of the primitive lateral borders.

The primary cause for such a morphological change is often to be found in a change of the mode of life—such as changes in mode of feeding, respiration, locomotion, etc. —and such a cause is suggested below (p. 595).

Summary of specializations.—That the procranidials, the anterior pair of primitive cephalic spines, either alone (*Olenellus* group) or coalesced with the parial spine (*Holmia* group), have by revolution to the rear come to form the genal spines is indicated by the following facts:

(1) That in the ontogenies of *Elliptocephala* and *Paedeumias* three different pairs of spines appear on the posterior border, whereas only three pairs of spines are known in any trilobite ontogeny; (2) that backward revolution of spines, such as is needed to bring the procranidial to the genal angle, has been observed in several forms during the ontogeny; (3) that the anterior branch of the facial suture, which in *Leptoplastus* borders the procranidial on the outer side, curves to the genal angle, indicating a revolution of the cheek; (4) that also the rostrum and the rostral suture (in other trilobites short and bounded at the ends by the connecting sutures) are here long, extending to the genal angle, indicating a stretching out of the doublure; (5) that the lack of dorsal facial sutures is most easily explained as the natural and inevitable further effect of these changes.

The remainder of the specializations mentioned earlier (p. 578) are perhaps of little significance in the present connection. The effective

coalescence of the tegmina of two anterior segments in the frontal lobe is one of the earliest cephalic specializations, characterizing trilobites in general and differentiating them from their more annelidan ancestors. It may perhaps be attributable to extensive modification of the appendages of these segments, enclosed as they were between the frontal lobe and the main body of the hypostome, and must be connected with feeding. The specialization of median spines and of thoracic pleura is another story, which I am making the subject of a separate paper, and need not be discussed here.

SYSTEMATIC POSITION OF THE OLENELLIDAE

A review of expressed opinions as to the cephalic structure and the destiny of the family.—Ever since its establishment, the systematic position of the family Olenellidae has been a subject of much discussion; and, considering its unique stratigraphic position and its possible zoological relationships, a just conception of that position is of some importance. This depends upon the interpretation of the cephalic structure, especially as regards the olenellid homologues of the anterior and posterior branches of the facial suture, and of the three pairs of cephalic spines recognizable in trilobites, with which the suture is closely related in position. Dependent on the interpretation of the cephalic structure are the deductions which have been made as to the origin and destiny of the family.

The specimens studied by Ford and by Walcott early showed them the locus of the *posterior* branch of the suture: [Ford, 1877, *Elliptocephala asaphoides* (fig. 5 and p. 270); Walcott, 1886, "*Mesonacis*" *vermontana* (p. 160), *Olenellus thompsoni* (p. 164), "*Mesonacis*" *fremonti* under name *Olenellus gilberti* (pp. 164, 172, and pl. 20, figs. 1e, 1g, 1h, 1i), and *Elliptocephala asaphoides* (p. 164)].

In Walcott's 1910 memoir several other forms show it, notably *Callavia bröggeri* (Walcott, 1910, pl. 27, fig. 1), *C. callavei* (pl. 28, fig. 1, under name *C. crosbyi*), *Olenellus thompsoni* (pl. 33, fig. 1, under the name *Paedeumias transitans*), "*Olenellus*" *canadensis* (pl. 38, figs. 1, 4, and 5), and *Olenellus gilberti* (pl. 36, fig. 14, and pl. 43, fig. 6). It should, however, be remembered that in *Holmia* and *Kjerulfia* two different lines, quite separate from one another, approximately occupy this position. In the forms mentioned as being figured by Walcott it is the vestige of the posterior branch of the suture that survives.

But it has perhaps been somewhat overlooked that Walcott never recognized the olenellid homologues of the anterior branch of the suture. For, though his figure of *Olenellus gilberti* shows sutures in front of the eyes comparable with those of *Paradoxides* (1886, pl. 18, figs. 1 and 1c; 1891, pl. 84, fig. 10) and his figures of "*Mesonacis*" *fremonti* show similar sutures (1886, pl. 20, fig. 1h; 1891, pl. 86, fig. 1h), such sutures did not exist on the specimens: those for *Olenellus gilberti* were inserted from

analogy with *Paradoxides*, and those given for "*Mesonacis*" *fremonti* were merely cracks across the narrowest part of the cheeks (1886, pp. 163, 164). Indeed, in 1910 regarding *Olenellus gilberti* he stated that no traces of the anterior facial sutures had been observed (1910, p. 327; see also pp. 242, 275). When in 1910 he refers to traces of facial sutures he means always those of the posterior branch. The only exception is where he refers to Moberg finding vestiges of a suture in front of the eye in *Kjerulfia* ("*Holmia*") *lundgreni* (idem, p. 291). Even in *Callavia callavei* (*C.* "*crosbyi*") and his "*Olenellus* cf. *O. gilberti*," which show the anterior branch of the suture—in the last named particularly well—he did not recognize it as such (idem, p. 275, pl. 28, fig. 1; pl. 41, fig. 1).

Though he saw no trace of the anterior branch of the suture, he could at that time confidently place the family in Beecher's Opisthoparia, because of the position of the posterior branch (1910, p. 235); for the significance of the procranidial spines and the metaparial head plan had not at that time been recognized.

Perhaps all other writers except myself (among them Beecher, Moberg, Swinnerton, Kiaer, Raymond, Ulrich, Warburg, Poulsen, Resser, Bell, and Stubblefield) have followed Ford and Walcott in regarding the Olenellidae as having a mesoparial (opisthoparian) head plan; i.e., as having for genal spine, a parial spine borne on the homologue of the free cheek (pareia). But these writers divide themselves into two groups: Ford, Beecher, Moberg, Walcott in his early writings, Kiaer, Ulrich, Warburg, and Bell have regarded the facial sutures in this family as vestigial and in a condition of symphysis: Walcott in his later writings, Swinnerton, Poulsen, and Stubblefield have regarded them as rudimentary, i.e., in an early stage of evolution, in preparation for their normal development in *Paradoxides*, though Walcott referred to their condition sometimes as that of "synthesis" (1910, pp. 236, 272, 275), at others, as that of "symphysis" (1910, pp. 250, 256, 327, 344).

My own view has already been expressed at some length (Raw, 1925, pp. 288–312; 1927, pp. 11–14, 132–142) and is more completely given in this present paper. It is based on the homologies of the different head parts in primitive trilobites and the evidence furnished by comparisons of the ontogenies of several species of olenellids with those of other primitive trilobites. Reasons have been given for deriving all trilobites from "heptacicephalic" ancestors furnished with dorsal compound eyes and facial sutures and the *three* pairs of head spines, and for the view that the olenellids are fundamentally different from mesoparial trilobites (Beecher's order Opisthoparia), in which the parial spines have become the genal spines, as well as from proparial trilobites (Beecher's Proparia), in which the metacranidial spines have become the genal spines.

The proparial head plan is the more primitive in that the metacranidial or posterior pair of spines

become genal spines in the same position. An interesting modification of this theory is enunciated by Stubblefield (1936 b, pp. 427–431), namely that the proparians are "permanently neotenous opisthoparians." In the typical mesoparial cephalon the parial or middle pair have revolved to the posterolateral angles to function as genal spines. Furthermore, in their ontogenies, several forms pass through a proparial stage before becoming mesoparial. This is now known to be the case in several trilobites. It was independently observed by me and by Warburg, and by each published in 1925. Richter (1932, p. 147, near bottom) was therefore in error in his criticism, later (Richter, 1933, p. 181, top) corrected. Unknown both to Warburg and myself it had also been illustrated by Poulsen (1923, p. 58) without its significance being noted.

In the olenellids, as I believe, a still more extensive revolution of the cheek has taken place; here the anterior pair, the procranidial spines, have revolved to the rear and have become the genal spines, carrying before them the margin of the pareia and the adjoining part of the anterior branch of the facial suture, with the connecting suture below it, thus stretching out between them the anterior margin of the cephalon into a semicircle, the rostrum beneath it into a crescentic strip, and the rostral and connecting sutures into the continuous marginal suture. This most specialized type of head plan is the metaparial (Raw, 1925, p. 311). Again in the ontogenies of olenellids, the first stage is a primitive proparial stage, which is succeeded by a primitive mesoparial, before the adult stage is reached, indicating that the metaparial is the most specialized of the three.

The revolution of the procranidial spines was, I believe, connected with burrowing habits. In the probably free-swimming protaspis stage the pairs of cephalic spines in some forms may still have been useful in their original position for retarding sinking. But when the ancestor took to burrowing (for which the typical body-form of olenellids is so well adapted) the anterior spines as well as the middle pair were in the way; in the Olenellidae they revolved to the rear; in the Paradoxidae the anterior spines aborted, and only the middle pair revolved rearward; in the Phacopidae both the anterior and the middle pair aborted.

The family, however, exhibits much variation, and in certain members of the genus "*Mesonacis*," as well as in *Olenelloides*, the procranidial spines occupy their primitive position at the anterolateral angles of the cephalon, probably through reversion (for example, "*Mesonacis*" *insolens* Resser and "*M.*" *bristolensis* Resser (Resser, 1928, pp. 7–9 and pl. 2), which might be attributed to their giving up the burrowing habit. Also, whereas in the *Olenellus* branch the available evidence indicates that the genal spines consist of procranidial spines alone, in the *Holmia* branch there is much reason to believe that in the genal spine we have the procranidial and parial spines

coalescent. Similarly in the *Olenellus* branch the intergenal spine can sometimes be seen to be a coalescence of the metacranidial and the parial. This is attributed to the crowding of the three spines of each cheek on its posterior border in typical forms.

Beecher's Proparia and Opisthoparia are not natural orders. They are groups of families with different grades of head plan, respectively proparial and mesoparial, to which the Olenellidae add another grade, the metaparial. Of these three grades the proparial is the most primitive and the metaparial the most specialized, notwithstanding that it characterizes a family of Lower Cambrian trilobites.

Corresponding to these widely divergent views as to the structure of the cephalon and its significance, similarly divergent views have been expressed as to the destiny of the family.

Walcott, when he believed that the Olenellidae were Middle Cambrian and had succeeded *Paradoxides*, derived *Olenellus* through *Mesonacis* from that genus and considered that their sutures were in a state of symphysis. And apparently he did not derive any other trilobites from them (1886, pp. 163–166).

When, however, he realized that they had preceded *Paradoxides*, he had to recast his ideas. In 1891 he was quite uncertain what significance to attach to the absence of sutures (1891, pp. 591, 592). But with the discovery of fresh forms, he had reached the view in 1910 that *Paradoxides* had evolved not from *Mesonacis*, with which he previously associated it, but from *Nevadia*, his "most primitive" genus, through *Callavia*, *Holmia* and *Wanneria* (1910, p. 249). He mentions *Redlichia*, *Alberteila* and *Zacanthoides* as retaining characters of the Mesonacidae; so that he derived at least these forms also from the family (1910, pp. 253, 254). My own views could hardly be further removed than they are from these maturer views of Walcott: *Paradoxides* could not be derived from any Olenellid; *Wanneria*, being by its hypostome and its great spine on the fifteenth postcephalic segment, a member of the *Olenellus* group, could not be derived from *Holmia; Holmia* having a more primitive cephalon than *Callavia* could not be derived from this; *Nevadia*, again, belonging to a different group, could not give rise to any of the other genera mentioned.

Swinnerton (1915, 1919) accepted Walcott's views as to the sutures, his association of the family with the Opisthoparia, and the same descendants that Walcott named. He represents on a figure of *Nevadia* copied from Walcott (supposed to be the most primitive olenellid) the suture lines as they are to arise in its descendants, in a typical opisthoparian position (1915, p. 540, fig. 3a); and he postulates a primitive order of trilobites, "micropygous," and "without free cheeks"—the "Protoparia"—to which the Olenellidae belong and from which in many separate lines of evolution suture lines arose (idem, pp. 493, 542; also 1919, p. 109).

Schwarzbach also (1934), when discussing the affinities of *Protolenus*, makes the Olenellidae ancestral to *Paradoxides*, *Protolenus*, *Redlichia*, and *Olenopsis*.

Poulsen (1927) agrees substantially with Walcott and Swinnerton. He considers that in olenellids we see the early stages of development of the posterior branch of the suture, which he regards as the limit of the eye segment; but he refuses to accept as anterior branches the lines regarded as such by Moberg and Kiaer, because they do not conform with opisthoparial courses. Indeed, he accepts the lines of frequent fracture across the narrow part of the extraocular cheek "as the anterior branch 'in statu nascendi' " (1927, p. 312). But he gives to the family a unique position of the highest importance, according it the rank of an order and making it the very root of the trilobite tree; for from it he derives, by one branch, all Beecher's Proparia and his Opisthoparia with the exception of the Conocoryphidae (his Suturicephalida; idem, p. 313), and at an earlier stage, presumably before the posterior suture commenced to form, he derives, by another branch, Beecher's Hypoparia together with the Conocoryphidae (his Integricephalida; idem, p. 315).

Stubblefield lately (1936 a, p. 68; 1936 b, pp. 421–427, 437) has associated his views with those of Swinnerton and Poulsen.

The views of Raymond (1917, 1928) and Bell (1931) both show a return to Walcott's earlier view. Both claim olenellids as Opisthoparia, with the anterior branch of the suture directed forward; but both were swayed by the same kind of evidence as misled Walcott—accepting cracks across the narrowest part of the extraocular cheek for sutures. Raymond was misled by a composite photograph I had prepared for Walcott—one of a cracked half cephalon. This had been photographed, and a direct and a reversed print obtained from the same negative, the two photos being then joined so as to present the whole head. (Raymond 1917, p. 206, reference to Walcott 1910, "pl. 42—this shows anterior portion of sutures also." See Walcott, 1910, p. 418.) Bell for his part (1931, figs. 1, 2, and 3) relied on specimens of *Olenellus thompsoni* crushed flat in the shale, but his photographs purporting to show the sutures merely display cracks, which are different in position on the two sides of the cephalon.

According to Resser (1928)—though doubtless he regarded the olenellids as opisthoparian, as he does not discuss their systematic position—they are unique in an altogether new way. For they possess a suture, of which there is no representative among other trilobites: in all the olenellids that he has reviewed, he claims the existence of *two* marginal sutures. In *Olenellus*, "*Mesonacis*," and *Paedeumias* these lie, the one, dorsal and intramarginal, the other marginal; these genera having, according to Resser, "marginal and epistomal plates separated by intramarginal and marginal

sutures" (1928, p. 5). In *Callavia* the same sutures are claimed to lie one marginal, the other ventral-intramarginal, bisecting lengthwise the crescentic plate to which the hypostome is attached (rostrum or epistome of Kiaer): *Callavia* thus having "both the marginal and epistomal plates situated on the under side" (1928, p. 6). This view, to which all other writers on the group are opposed, I have controverted (Raw, 1936 b, pp. 245, 246).

On the other hand, Moberg had already in 1899 described and figured his *Holmia lundgreni* with the anterior branch of the suture running from the front of the eye and curving round towards the genal angle, as well as the posterior branch, both of them regarded by him as in a condition of symphysis. And he had recognized the same features in *Holmia kjerulfi* (1899, pp. 323–324; pl. 14, figs. 2a, 2b, 3, and 4).

Kiaer (1916) figures and describes the suture lines in the same position in *Kjerulfia lata* (1916, p. 81; and p. 60, fig. 9; p. 67 fig. 11e; p. 74, fig. 12). Regarding them as in a condition of symphysis, he could not think that nature had ankylosed sutures in this family, only to redevelop them in its descendants. And from a careful comparison of the Olenellidae and Paradoxidae he concludes that "they must be regarded as two parallel families that have developed independently of each other from common ancestors" (idem, p. 92). This statement, I regret, was not known to me when I wrote on their ontogenies (Raw, 1925, pp. 266–279 and 286–309).

My own studies in the ontogenies of trilobites support this conclusion of Kiaer's. In the ontogenies of primitive mesoparial trilobites, such as *Paradoxides*, the proparial stage precedes the mesoparial; and in the ontogenies of olenellids both proparial and mesoparial stages precede in the same order the attainment of the adult or metaparial stage: we could not therefore, except by a reversal of the previous evolution, derive proparial from mesoparial, nor mesoparial from metaparial. Further, since the adoption of the metaparial type of head plan involved loss of the facial suture, through the extended marginal suture being sufficient for ecdysis, the derivation of Paradoxidae from Olenellidae would entail reversal of evolution in several different features at the same time. The only trilobites to which the Olenellidae could possibly be ancestral would be forms without facial sutures and with an extended marginal suture.

The strongest divergence of the various views has been concerned with the following three questions:

1. The significance to be attached to the lack of facial sutures, i.e., the lack of a parting across the dorsal face: whether the cephalon preserves a primitive "protoparial" condition—before any facial suture was evolved (Walcott, Swinnterton, Poulsen)—or is specialized by secondary ankylosis of sutures; in other words whether the traces of sutures are in an early stage of evolution or are vestigial.

2. The position of the trace of the anterior branch of the suture: whether this runs towards the genal angle (Moberg, Kiaer, Warburg, Raw) or towards the anterolateral border (Swinnerton, Raymond, Poulsen, Bell).

3. The homology of the genal spine: whether it is homologous with the cheek spine of *Paradoxides*, as all others believe, or is homologous with the procranidial spine of *Leptoplastus*, as I claim is proved both by ontogeny and structure.

The answers to these questions carry with them the conclusions regarding the destiny of the family.

The various views mentioned in this brief summary may be tabulated as follows:

Summary of Interpretations

Cephalon protoparial; sutures in process of origin—Stubblefield, 1936 a, 1936 b.
- Root stock of whole trilobite tribe—Poulsen, 1927.
- Ancestral to Paradoxidae and Zacanthoidae—Walcott, 1910; Swinnerton, 1915, 1919, 1923; Schwarzbach, 1934.

Cephalon mesoparial; sutures in symphysis; no trilobite descendants
- Anterior branch of suture with forward course—Ford, 1881; Walcott, 1886; Beecher, 1897, 1900; Raymond, 1917, 1928; Ulrich, 1922; Bell, 1931.
  - Additional marginal suture—Resser, 1928.
- Anterior branch of suture with backward course—Moberg, 1899; Kiaer, 1916; Warburg, 1925.

Cephalon metaparial; sutures in symphysis; no trilobite descendants—Raw, 1925, 1927, 1936 a, 1936 b

ORIGIN OF THE OLENELLIDAE

The influence of habitat.—Among known trilobites the Olenellidae are an exceptionally compact group. This is shown by the great number of their common characters. Affinities among trilobites, as is universally agreed, are indicated most reliably by the characters of the cephalon. Within this family the range of variation in the cephalon—its dorsal surface, its doublure, and the hypostome so far as known—is very limited.

The type of thoracic segment and the pygidium are also very constant. Unfortunately the doublure and the hypostome of *Nevadia* and of some other forms is not yet known; but the known range of characters in the family is so small that, if it is not greatly extended by further knowledge, it would seem very probable that the family is monophyletic. The characters of Olenellidae remove them altogether from each of Beecher's so-called orders—"Proparia," "Opisthoparia" and "Hypoparia." Their relations to members of the first two of these groups have already been discussed (Raw, 1925, pp. 303–314) and summarized (Raw, 1927, pp. 131–141, and table, p. 140). The Olenellidae, the mesoparial Paradoxidae, and the proparial Phacopidae have been referred to a common ancestor with three pairs of head spines.

Typical olenellids and paradoxids and primitive phacopids, are all adapted by their body form for a shallow burrowing or ploughing mode of life (Dollo, 1909, pp. 408, 409, figs. 7, 8). Their usual locomotion was perhaps a labored and slow crawling and pushing of their way through the surface mud of the sea

floor. The eyes, each a low half cylinder, with vision all round—to the rear as well as to the front—indicate a mainly sedentary existence; and their level would put a limit to the habitual extent of burial. Perhaps usually they were up to the eyes in mud.

If these families are related to one another, as in 1925 I claimed, it may be possible, from close comparisons between them, to suggest causes for their divergences. And the factor that I believe caused the evolution of the olenellids and their divergence from the common stock was the earlier adoption by them of this ploughing mode of life—early both in the phylogeny and the ontogenies. In the olenellid ancestry it was adopted while they were still in the heptacicephalic stage, before any of the three primitive pairs of spines had aborted. Perhaps also they took to burrowing early in life. And as both the procranidial and the parial spines impeded such progression through the mud, there was relatively rapid revolution of both these pairs and a stretching out of the whole anterior border to the rear. The metacranidials, primitively at the posterolateral angles, were relatively quickly superseded there by the parials; and these in their turn were relatively quickly superseded by the procranidials. The concomitant stretching out of the rostral suture into a semicircle and the revolution of the anterior branches of the facial sutures to the genal angles led inevitably, as explained above, to the supersession of the dorsal and ventral sutures by the marginal suture acting alone; and this in its turn led to ankylosis along the dorsal facial sutures. On this theory the heptacicephalic-proparial and the heptacicephalic-mesoparial stages were relatively quickly passed through in the phylogeny, after the adoption of the burrowing habit.

The excessive thinness of the test also is probably of considerable significance in this connection. The test of the heptacicephalic ancestor would be much thinner still. This factor makes the original adoption of the ploughing habit by that ancestor easy to conceive. It also facilitates conception of the revolution of the cheeks and spines and the stretching out of the anterior border. Had the integument been thick and rigid, anterolateral and lateral spines would perhaps have offered such resistance that burrowing would have been inhibited till they had aborted, when no stimulus to revolution would remain.

The early paradoxids, on the other hand, perhaps took to burrowing later in the phylogeny, or later in the ontogeny, or they burrowed less; in any case, their different habits might be due to difference of habitat. And though the parials superseded the metacranidials as main cheek spines, the procranidials aborted before they reached the genal angle.

A further removal in the same direction characterized the early phacopids, in which the parials as well as the procranidials aborted before they could be revolved to the rear.

This new conception can be fitted into the "scheme of inferred diver-

gences" previously submitted (Raw, 1917, p. 140). Whatever the exact causes and modes of the divergences, the cephalon characteristic of the Olenellidae is distinguished from that of all other trilobites at present determined by its metaparial grade of structure. But associated with this highly specialized head plan are numerous primitive features. It is as if the mode of life, which determined this metaparial specialization, favored survival, causing the family to survive, notwithstanding that it remained so primitive in several other respects.

Unique in the possession of this specialized metaparial grade of head plan, and removed from mesoparial and proparial trilobites still further by the loss of the dorsal facial sutures, the Olenellidae merit the rank of an independent order. This has already been accorded them by Poulsen, though his views as to their structure and destiny are so entirely different from mine.

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EUPACHYCRINUS AND RELATED CARBONIFEROUS CRINOID GENERA

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ABSTRACT

The genus *Eupachycrinus*, long used as a catch-all for diverse crinoid types, is redefined and the genotype refigured and redescribed. The species hitherto referred to *Eupachycrinus* have been segregated into three genera, two of which are new. *Phanocrinus*, n. gen., is an upper Mississippian genus approximately contemporaneous with *Eupachycrinus*. *Ethelocrinus*, n. gen., is from the Pennsylvanian.

The genus *Eupachycrinus* was founded by Meek and Worthen in 1865 (not 1855 as commonly cited in the literature) with *Graphiocrinus quatuordecimbrachialis* (*14-brachialis*) Lyon as the genotype. Lyon's original description of the type species (1857) was brief and his illustrations perhaps not the best possible, but they are adequate so far as the fixation of specific and generic characters are concerned. With the passing of the years the original genotype has been more or less forgotten, and gradually the concept of the genus has become one characterized by such forms as *Zeacrinus formosus* Worthen. This has been due primarily to the fact that no comprehensive study of the American Inadunata had been made by a competent authority such as Wachsmuth other than in the early and preliminary survey in the "Revision of the Paleocrinoidea." The genus *Eupachycrinus* then has generally been used very broadly to include almost any Carboniferous Inadunata with a bowl- or basin-shaped dorsal cup with an invaginated base and long stout rami, either uniserial or biserial. Bather (1900, p. 181) in his discussion of the family Cromyocrinidae, in which he placed *Eupachycrinus*, says:

> There is much confusion in the nomenclature of this and allied families, and the following names may not be used in what will ultimately prove the correct sense.

It seems desirable therefore to redefine *Eupachycrinus* in modern terms, with the structural characteristics of the genotype as a foundation, and to arrange the alien species hitherto referred to the genus in genera that have biologic and stratigraphic value. This procedure makes necessary the erection of two new genera, one of later Mississippian age and one of Pennsylvanian age. The genera are easily determinable and seem to have definite stratigraphic value.

Genus EUPACHYCRINUS Meek and Worthen, 1865

Eupachycrinus MEEK and WORTHEN, *1865*, Acad. Nat. Sci. Philadelphia, Proc., p. 159. —MEEK and WORTHEN, *1866*, Illinois Geol. Survey, vol. 2, Paleontology, pp. 177, 178. —WACHSMUTH and SPRINGER, *1880*, Revision of the Paleocrinoidea, pt. 1, pp. 133–139; *1879*, Acad. Nat. Sci. Philadelphia, Proc., pp. 358–364.—WACHSMUTH and SPRINGER, *1886*, Revision of the Paleo-

crinoidea, pt. 3, sec. 2, p. 249; *1886*, Acad. Nat. Sci. Philadelphia, Proc., p. 173.—BATHER, *1900*, in Lankester, Treatise on Zoology, pt. 3, Echinoderma, p. 181.

The crown has a stout, compact build, the rami being heavy and relatively short. The dorsal cup is bowl-shaped with a deeply invaginated base. The infrabasals are small and concealed within the basal pit. As a rule the infrabasals have separated from the basals and presumably have fallen within the cavity of the dorsal cup. The basals are large, and the proximal portions flex inward abruptly to form the basal pit. They are hexagonal in outline except the posterior and right posterior basals, which are heptagonal. The radials are broad and low, with the articulating facet extending the full width of the radial. There are three anal plates in the posterior interradius. The radianal is large and pentagonal in outline, resting below on the posterior and right posterior basals. Laterally it abuts against the right posterior radial and anal x. Above it supports the right tube plate. Anal x rests below on the posterior basal. Laterally it abuts against the radianal and the left posterior radial. On its right sloping shoulder it supports the right tube plate. Above it supports the left tube plate. The ventral sac is unknown.

The first primibrach is axillary. The anterior ray has two equal rami. In the other rays in the species where the arm structure is known the anterior half bifurcates again on the first secundibrach, giving three rami. Judging by the trend in the derived genus *Ethelocrinus*, it is possible that within *Eupachycrinus* forms will be found in which four rami to a ray occur. The rami are relatively short, stout, and compactly biserial.

The column so far as known is round and composed of alternate nodals and internodals.

Genotype.—The genotype as chosen by Meek and Worthen is *Graphiocrinus quatuordecimbrachialis* (*14-brachialis*) Lyon.

Horizon.—The genus *Eupachycrinus* so far as known at present is restricted to the upper Mississippian of the United States, though it probably extends into the Pennsylvanian.

The species from China referred to *Eupachycrinus* by Tien (1926) on the advice of Springer do not belong in the *Eupachycrinus* series. They were better assigned to *Cromyocrinus* or *Ulocrinus* among described genera.

EUPACHYCRINUS QUATUORDECIMBRACHIALIS (Lyon)

Plate 84, figures 4–7

Graphiocrinus 14-brachialis LYON, s.s., *1857*, Kentucky Geol. Survey, Rept. 3, pp. 477–479, pl. 1, figs. 2, 2a, 2b.

Eupachycrinus 14-brachialis (Lyon). MEEK and WORTHEN, *1865*, Acad. Nat. Sci. Philadelphia, Proc., ser. 1, vol. 17 (ser. 2, vol. 9), p. 159.—MEEK and WORTHEN, *1866*, Illinois Geol. Survey, Paleontology, vol. 2, sec. 2, p. 177.

Graphiocrinus quatuordecembrachialis Lyon. S. A. MILLER, *1877*, The American Palaeozoic fossils, 1st edition, p. 81.

Eupachycrinus quatuordecembrachialis (Lyon). S. A. MILLER, *1883*, The American Palaeozoic fossils, supplement to first edition, called second edition on title page, p. 282.—S. WELLER, *1898*, U. S. Geol. Survey, Bull. 153, p. 266.

Eupachycrinus quatuordecimbrachialis (Lyon). WACHSMUTH and SPRINGER, *1879*, Acad. Nat. Sci. Philadelphia, Proc., p. 363; *1880*, Revision of the Paleocrinoidea, pt. 1, p. 139.

This species, so far as known, is represented in the collections by one specimen, the holotype. Fortunately the crown of the type is in an excellent state of preservation, and all essential details of structure can be made out clearly. The distal portion of the arms is lacking, and the dorsal cup is somewhat compressed in the plane of the right anterior radius—left posterior interradius. The plates of the posterior interradius are somewhat eroded, and the infrabasals have become detached from the basals, probably dropping into the cavity of the dorsal cup as is commonly the case in the genus. Lyon's original figures of the species, consisting of anterior and basal views and a plate diagram, are essentially correct. Similar views are given in this paper together with a posterior view.

The dorsal cup is basin-shaped, with slightly diverging walls and a truncate base as seen in lateral view. Owing to the tumid character of the plates there appears to be a constriction of the cup at the arm bases. The cup has a height of 11 mm. and a diameter of about 20 mm. It is composed of highly tumid, massive plates. The base is deeply invaginated, the pit having a depth of approximately 8 mm. from the plane truncating the base.

The infrabasals have become detached from the basals and probably lie within the cavity of the dorsal cup. The diameter of the infrabasal disk is not in excess of 3 mm., which would make the infrabasals very small. The infrabasals normally lie at the apex of the basal pit, their position being above the level of the basals as seen in an exterior lateral view. The basals have an average height of about 7 mm. on the exterior, and the inner portion forming the basal pit has a height approximately 1 mm. greater. The depth of the pit is, of course, greatly accentuated by the tumidity of the basals. The fragment of column lying in the pit was removed before the specimen was photographed to give a better idea of the size and depth of the cavity and then replaced. As seen in basal view the basals have distinctly petaloid outlines with acute apices. From the periphery of the pit inward there is a well-marked median groove on each basal. The basals are pentagonal in outline except the posterior and right posterior, which are hexagonal. The posterior basal supports anal x on its upper truncated surface and the radianal on its upper right sloping shoulder. The right posterior basal supports the radianal on its upper left sloping shoulder. The radials are large, having an average width of about 11 mm. and an average height of about 7 mm., excepting the right and left posterior radials. The anterior radial is the largest, whereas the right and left posterior radials are considerably smaller than the others. They are pentagonal in outline. The articulating facet extends the full width of the radial. The radial-IBr suture is coarsely crenulate. The radials are highly tumid, the sides rising steeply from the margins. The left posterior radial supports anal x on its upper right shoulder. The right posterior radial abuts laterally against the radianal and barely contacts the right tube plate.

The radianal is large, measuring 9.5 mm. in height by 6 mm. in maximum width. It is pentagonal in outline. Below it wedges deeply between the posterior and right posterior basals. Laterally it abuts against anal x and the right posterior radial. Above it supports the right tube plate. Anal x has a height of 5 mm. and a maximum width of 5.8 mm. It is pentagonal in outline. Below it rests on the posterior basal, laterally it abuts against the left posterior radial and the radianal. Above it supports the right tube plate on its upper right shoulder and the primaxil of the left posterior ray on its upper left shoulder. The right tube plate is large, having a maximum length of 6.8 mm. and a maximum width of 5 mm. It is heptagonal in outline. Below it rests on X, RA and the right posterior radial. Laterally it abuts against the primaxils of the right and left posterior rays. Above it presumably supports tube plates, which, however, cannot be seen. The structure of the ventral sac is unknown.

The first primibrachs of all the rays are axillary. The primaxils extend the full width of the radials or even reach beyond their margins. In the left posterior ray there is a considerable overlap toward the posterior interradius, the primaxil making contacts with anal x and the right tube plate. In all cases except the posterior interradius the primaxils abut laterally. The surface of the primaxils rises gradually and then more abruptly from the margins, culminating in a submedian high rounded boss. The superior faces of the anterior primaxil are subequal in length. In the other primaxils the face bearing the arm that divides is

considerably longer than the other. In the anterior ray there are two equal rami borne by the primibrach. In the other rays the anterior half bears two rami. The first secundibrach in the bifurcating half of the ray is axillary. The secundaxils are large and nodose. Laterally they abut against the first secundibrachs of the adjacent rays and of the other half of their own rays. The first secundibrachs of the undivided rami and the first tertibrachs of the divided halves are large and extend the full width of the rami. In most cases biserial brachials appear immediately after these large brachials. The rami are broad with flattened slightly convex backs. Judging by the rate of taper the rami were relatively short. The sides of the rami are flattened, as all the rami, with the possible exception of those on each side of the posterior interradius, are closely apposed, each to its neighbor. The rami are biserial.

In the basal concavity lies a fragment of column that was so figured by Lyon. Whether it belongs to the specimen cannot be told. It is about the right diameter. Such as it is, it consists of alternate nodals and internodals and does not show the lumen clearly.

Type.—The original type of Lyon, bearing the number 102 of his manuscript catalogue, is now number S 3817 in the Springer collection of the U. S. National Museum.

Occurrence.—The specimen came from the Chester (Sainte Genevieve) of Crittenden County, Kentucky.

Remarks.—This species was originally described by Lyon as *Graphiocrinus 14-brachialis*. The trivial name was first latinized so far as I know by Miller (1877, p. 81) as *quatuordecembrachialis*. There seems to be no precedent or ruling as to whether Lyon's original name could be used. In entomology similarly derived names are frequently used in the text as combinations of Arabic numerals and Latin suffixes for the sake of brevity. In the absence of a precedent, I have adopted the latinized form modified to the preferable *quatuordecimbrachialis* as of Wachsmuth and Springer, using the less cumbersome *14-brachialis* in the text. A parallel example is to be found in *Ecphora quadricostata* (Say). Described originally as *Fusus 4-costatus* Say (1824), the name was changed to *Fusus quadricostatus* by Conrad (1830). The specific name has been used in the emended form by subsequent authors.

EUPACHYCRINUS SPARTARIUS S. A. Miller

Plate 84, figures 8–14

Eupachycrinus spartarius S. A. MILLER, *1879*, Cincinnati Soc. Nat. Hist., Jour., vol. 2, p. 38, pl. 8, fig. 2. (Author's separate, pp. 8, 9.)

In order to define and illustrate more accurately the generic characters of *Eupachycrinus* it seems desirable to give a brief description of another species, *E. spartarius* Miller. This species is represented in the collections by a considerable number of specimens in an excellent state of preservation, representing not only adults but immature stages as well. The species has been chosen because, although being a characteristic *Eupachycrinus*, it shows many variations from the type species *E. 14-brachialis*.

The species is of medium size, the crown figured having an approximate height of 43 mm., of which the dorsal cup takes up somewhat less than one-seventh. The relatively short stout rami tapering rapidly distad and the broad low dorsal cup gives the crown the stout, compact build that seems to be characteristic of the genus. The dorsal cup is bowl-shaped, being broad and low with curving sides. The plates are moderately convex instead of being highly tumid as in *E. 14-brachialis*, which superficially gives the cup a strikingly different aspect. The dorsal cup has an average height of 6 mm. and an average diameter of about 16 mm. The base is deeply invaginated. The surface of the plates is covered with low indistinct confluent pustules.

The infrabasals form a pentagon 3.6 mm. in diameter. As is usual in the genus the infrabasals become detached from

the basals in most specimens and probably fall within the cup. The proximal portions of the basals turn inward abruptly, forming a basal pit 6 mm. in diameter and 3 mm. in depth. The basals are large, having an average height of 5.5. mm. They are hexagonal in outline except the posterior and right posterior, which are heptagonal. The relative outline and relations to the anal plates are essentially as in *E. 14-brachialis*, except that the upper left sloping shoulder of the right posterior basal supporting and radianal is much shorter in *E. spartarius*. The radials are broad and low, with an average width of about 8 mm. and an average height of about 5 mm. The articulating facet extends the full width of the radial. The radianal is relatively smaller but has the same relations to the adjacent plates as in *E. 14-brachialis*. Anal x instead of being overlapped by the primaxil of the left posterior radius abuts laterally against it, bearing a tube-plate on its upper truncated face. The right tube-plate supports a single tube-plate above. The structure of the ventral sac is unknown.

The number and arrangement of the axillaries are the same as in *E. 14-brachialis*. The rami are closely appressed in all the rays and interrays except for a short distance above the cup in the posterior interradius. The sides of the rami are flattened, but the backs are rounded. The rami are compactly biserial. The rami are relatively stout, reaching their maximum width about midway of their length and then tapering rapidly distad. As noted above, the rami have a length in excess of six times the height of the dorsal cup.

There are three very young individuals of this species in the Springer collection, the complete crown of the smallest having a height of but 10 mm. There is very little difference in the relative proportions and shape of the dorsal cup and arms of these specimens outside the customary juvenile characters. The arms are cuneate instead of biserial, and the length of the axillaries is excessive in relation to their width. This is particularly true in regard to the secundaxils, which are nearly two-thirds the length of the same ossicles in the adult. The right tube-plate lies somewhat deeper in the dorsal cup than in the adult. On the whole, however, the specific characters are unmistakable.

Occurrence.—The suite of specimens in the Springer collection in the U. S. National Museum was collected by Wachsmuth from the Glen Dean member of the Chester at the famous locality in Sloans Valley, Pulaski County, Kentucky.

Genus PHANOCRINUS Kirk, n. gen.

Genotype.—As genotype of the new genus *Phanocrinus* I have chosen the well-known *Zeacrinus formosus* Worthen. This species has been referred to *Eupachycrinus* for many years and indeed has rather generally come to be considered typical of that genus. *Phanocrinus formosus* (Worthen) is represented in the collections by numerous beautifully preserved specimens, most of them found in the Chester of Pulaski County, Kentucky.

Description.—The dorsal cup is basin-shaped, with a height usually not more than one-half the diameter. The basal area is shallowly depressed or has a small basal pit.

The infrabasals are five in number and form a small pentagonal disk, extending, however, beyond the proximal columnal. The basals are pentagonal with the exception of the posterior and right posterior, which are hexagonal. The right posterior basal supports the radianal, and the posterior basal supports the radianal and anal x. The radials are considerably wider than high. The entire face of the radial is occupied by the arm-facet. There are three anal plates in the dorsal cup, ra, x, and rt. The radianal is relatively large, supporting anal x and the right tube-plate. Anal x supports the right tube-plate on its upper right shoulder and another tube-plate on its upper truncated face. It abuts against

the primaxil of the left posterior radius. The right tube-plate abuts against the primaxil of the right posterior radius and supports one or two tube-plates above. The ventral sac is unknown.

The arms either remain undivided, giving 5 rami, or bifurcate on the first primibrach, giving 10 rami. The rami have a length of about ten times the height of the dorsal cup and are composed of quadrangular ossicles. The pinnules are long and relatively stout.

The plates of the dorsal cup are moderately convex and carry obscure confluent pustules.

The column is circular in cross section, slender, and composed, so far as known, of alternate wide and narrow ossicles. The axial canal is pentalobate.

Horizon and geographic range.—The genus, so far as known, is restricted to rocks of late Mississippian (Chester) age. In the United States the genus is known to range from Kentucky to Oklahoma. In Scotland (Wright, 1925) it is found in the "Hurlet limestone" or Seafield Tower limestone.

Remarks.—The genus as defined differs chiefly from *Eupachycrinus* in the structure of the arms. In *Phanocrinus* the rami are proportionately very long, stout, and composed of quadrangular ossicles. There are but one or two rami in each radius. The dorsal cup is relatively lower than in *Eupachycrinus* and can best be described as basin- or saucer-shaped. The basal area is depressed but is not as deeply invaginated as tends to be the case in *Eupachycrinus*. This is a character that should not be stressed, however.

Wright (1926) has made a careful study of the variation in the anal plates as found in more than 200 specimens of *Phanocrinus calyx* (McCoy) from Scotland. The wide variation from the norm constantly to be found among the Inadunata of the Carboniferous has always been a stumbling block in the path of the systematist. The painstaking work of Wright on large series of *Phanocrinus* and *Zeacrinus* should be at once a guide and a warning to workers in the Inadunata. In his series Wright has the normal three anals, varying considerably, however, in relative size and position, two anals, one anal as in *Delocrinus*, and with no anal in the cup. It is probable, as Wright suggests, that he is dealing with an unusually variable and plastic group. It is possible that in this case we are dealing with new arrivals that are responding to the stimulus of changed environment. Certainly no comparable variation of structures has been found in the American specimens examined by me, although nearly as many specimens have been available for study.

Wright (1926, pp. 147–149) questioned the propriety of placing *Cupressocrinus calyx* McCoy in *Eupachycrinus*. In an earlier paper (1925) he had cited the species as *Eupachycrinus?*, following Bather (1912), who had provisionally referred the species to *Eupachycrinus*. Having been furnished specimens of *Phanocrinus formosus* by Springer as typical of *Eupachycrinus*, Wright finally felt impelled to place his species "without qualification" in *Eupachycrinus*. Had Wright been furnished a photograph of *E. 14-brachialis* or a specimen of the closely related *E. spartarius*, it is quite certain that his conclusions would have been different.

PHANOCRINUS FORMOSUS (Worthen)

Plate 84, figures 1, 2

Zeacrinus formosus WORTHEN, in Meek and Worthen, *1873*, Illinois Geol. Survey, vol. 5, p. 549, pl. 21, fig. 2.

There are numerous complete crowns of this species in the Springer collection in the U. S. National Museum. I have chosen one for illustration and measurement that runs somewhat above the average size.

The dorsal cup is basin-shaped, with a flattened base in profile. The sides of the cup constrict slightly at the upper margin. The dorsal cup has a height of 6 mm. to the arm bases and a maximum diameter of 16 mm. The basal region is

depressed, forming a shallow concave area which involves approximately one-half of the height of the basals.

The infrabasals, five in number, form a small pentagonal disk that usually has separated from the basals and dropped within the cup. This has happened in the specimen figured, where the infrabasal pentagon has a diameter of 4 mm. The basals are of approximately equal height and width and are pentagonal in outline with the exception of the posterior and right posterior, which are hexagonal. The lower portions of the basals flex inward and form a shallow concave basal area. The right posterior basal supports the radianal on its upper left sloping shoulder. The posterior basal supports the radianal and anal x. The radials with the exception of the right and left posterior have an average height of about 5.5 mm. and an average width of 8.5 mm. The arm-facet occupies the entire upper face of the radial. The right posterior radial abuts against the right tube-plate and the radianal. The left posterior radial abuts against the anal x.

There are three anal plates in the dorsal cup. The radianal is large, pentagonal, supporting anal x on its left upper shoulder and the right tube-plate on its upper truncated surface. Anal x is hexagonal, supporting the right tube-plate on its upper right sloping shoulder and a tube-plate on its distal truncated face. Anal x abuts against the primaxil of the left posterior ray on its upper left sloping shoulder and reaches to about two-thirds the height of the primaxil. The right tube-plate abuts against the primaxil of the right posterior ray on its upper right sloping shoulder and the tube-plate following anal x on its left shoulder. The ventral sac is unknown.

There is a single primibrach in each radius, which is axillary. Adjacent primaxils abut laterally, except in the posterior interradius. In all radii there are two long stout uniserial rami. The arms in the specimen figured have a length of about 55 mm., which gives a length of nearly ten times the height of the dorsal cup. The rami abut laterally from their points of inception, except in the posterior interradius. Even here the first secundibrach of the right posterior radius is in contact with the second secundibrach of the adjacent ramus of the left posterior radius. The rami widen slightly to about one-half their height and then taper gradually distad. The backs of the rami are rounded and their sides flattened. The arm ossicles are quadrangular with no signs of cuneate form except for an occasional crowded ossicle. The pinnules are long and stout.

The plates of the dorsal cup are convex and covered with indistinct low confluent pustules.

The column is circular in section, slender, and composed, so far as known, of alternate wide and narrow ossicles. The axial canal is pentalobate.

Occurrence.—The superb specimens of *Phanocrinus formosus* in the Springer collection in the U. S. National Museum were collected by Wachsmuth at Sloans Valley, Pulaski County, Kentucky, from the Glen Dean member of the Chester.

Figured specimen.—The figured specimen, which may without question be referred to *Phanocrinus formosus* (Worthen), is in the Springer collection in the U. S. National Museum. The specimen came from a lot identified by Wachsmuth.

PHANOCRINUS GRACILIS (Wetherby)
Plate 84, figure 3

Cromyocrinus gracilis WETHERBY, *1880*, Cincinnati Soc. Nat. Hist., Jour, vol. 2, p. 248, pl. 16, figs. 2–2*e*.—S. A. MILLER, *1883*, The American Palaeozoic fossils, 2d edition, p. 281.

Eupachycrinus gracilis (Wetherby). WACHSMUTH and SPRINGER, *1886*, Revision of the Paleocrinoidea, pt. 3, sec. 2, p. 249; *1886*, Acad. Nat. Sci. Philadelphia, Proc., p. 173.

This species has been figured and briefly described to bring out interesting variations in structure from those shown by the genotype.

The dorsal cup is relatively higher than in *Phanocrinus formosus*, having a

height about one-half the width. There is a well-defined narrow basal pit, only about one-third the proximal portion of the basals being involved in its formation. The only other structures worth noting in the dorsal cup are the anal plates. The right tube-plate abuts against and reaches up to only about one-half the height of the first primibrach of the right posterior radius. It supports a tube-plate on its upper truncated face. Anal x extends upward to only about one-third the height of the first primibrach of the left posterior radius. It supports a tube-plate above and the right tube-plate on its upper right sloping shoulder.

The structure of the arms is the most interesting feature of the species. Each radius bears a single long stout ramus. The first primibrach is large, and in most cases its distal face is somewhat sloping. In only one specimen seen, in one radius, is the first primibrach axillary. The rami increase rapidly in size distad to about one-third their length, then gradually taper for the remainder of their length. The backs of the rami are rounded, and only for short distances do the sides show any flattening due to lateral appression. The arm ossicles are quadrangular and bear stout pinnules on alternate sides. As in *Phanocrinus formosus*, the arms have a length of about ten times the height of the dorsal cup.

Occurrence.—The specimens studied were collected by Wachsmuth in the Glen Dean member of the Chester at Sloans Valley, Pulaski County, Kentucky, which was doubtless the source of Wetherby's material, as he was the original discoverer of the famous locality.

Figured specimen.—The specimen figured is in the Springer collection in the U. S. National Museum.

Genus ETHELOCRINUS Kirk, n. gen.

In the Pennsylvanian occurs a group of crinoids that are apparently derived out of *Eupachycrinus*. Well-preserved crowns are available for study from Kansas City, Missouri. Judging by dorsal cups alone, which seem to be distinctive, the generic group has a wide geographic range. For this group a new generic name, *Ethelocrinus*, is here proposed, with *Eupachycrinus magister* Miller and Gurley as genotype.

Structurally *Ethelocrinus* differs from *Eupachycrinus* mainly in the fact that the right tube-plate has migrated upward completely out of the dorsal cup, with consequent modifications of shape and relative size of the radianal and anal x. The other modifications are quantitative rather than qualitative, being for the most part normal orthogenetic developments of characters present in *Eupachycrinus*. The cirriferous column of *Ethelocrinus* is probably characteristic, but lacking knowledge of the column of *Eupachycrinus* this character cannot be used at present.

The variability in the number and relative proportions of the plates of the posterior interradius as described by Wright (1926) in the British species *Phanocrinus calyx* McCoy is noted elsewhere. In this one species the types of posterior interradius found in no less than four related Carboniferous genera are to be found: *Phanocrinus* (or *Eupachycrinus*), *Ethelocrinus*, *Delocrinus*, and *Erisocrinus*. This is the most extreme case of such variation known at present but may be duplicated when we have an extensive suite of specimens representing an unstable stage in some other genetic series. It is nevertheless necessary to provide such a group as I have denominated as *Ethelocrinus* with a generic name. Representing a definite stage in the evolution of the posterior interradius and with correlated characteristics and wide geographic range, the genus will prove of value.

The dorsal cup is typically low and basin-shaped, with a wide flattened base as viewed in profile and with a tendency to constriction at the arm bases, which at times is quite pronounced. The base is usually excavate. The plates are convex and the surface covered with coarse

granules that tend to become confluent. At times the surface ornamentation is highly accentuated, resulting in strongly developed rugosity.

The infrabasals form a pentagon that averages at least two times the diameter of the column. The sutures between the infrabasals are well-defined. The basals are large and hexagonal except the posterior and right posterior, which are heptagonal. The radials are broad and relatively low. The articulating facet occupies the full width of the radial. There is a sharply defined transverse articulating ridge. Projecting inward are broad shelves carrying the muscle-fossae. When viewed from above these inward projections of the radials give a false impression of exceedingly thick, massive plates. There are but two anal plates in the cup, the radianal and anal x. In one specimen from the Pennsylvanian of Colorado referable to the genus anal x has migrated out of the cup. The radianal in this specimen still holds its oblique position. The radianal is large, quadrangular, resting below on the posterior and right posterior basals and supporting the right posterior radial and anal x. Anal x in most specimens is hexagonal. Below, it rests on the posterior basal and the radianal. Laterally it abuts against the right and left posterior radials. Above, it supports two tube-plates. The superior faces of anal x are subequal in size, or unequal. When unequal, curiously enough it is the face supporting the right tube-plate that is the smaller. The ventral sac is unknown.

The arms are essentially those of *Eupachycrinus* except as to the number of rami, so far as these are known in the two genera. In *Eupachycrinus* the normal number of rami seems to be 14. In *Ethelocrinus magister* the number of rami is variable, 16 seeming to be a common number—2 in the right and left anterior rays and 4 each in the others. In one specimen from Kansas City the right and left anterior rays have 3 rami, which with 4 rami in each of the other rays gives a total of 18. I do not think that the number of rami in these Pennsylvanian species of *Ethelocrinus* is of even specific value within the range indicated above.

The column is circular in cross section and in its proximal portion composed of alternate nodals and internodals. An interesting feature in *Ethelocrinus magister* is that whorls of cirri are borne by the column to within a short distance of the crown.

Genotype.—As genotype I have chosen *Eupachycrinus magister* Miller and Gurley (1890) from the Pennsylvanian of Kansas City, Missouri. *Eupachycrinus sphaeralis* Miller and Gurley, described in the same paper, is doubtless a synonym of *E. magister*. In the Springer collection in the U. S. National Museum, *Ethelocrinus magister* is given as a synonym of *Eupachycrinus bassetti* Worthen. This assignment, judging by Worthen's figures and description, both of which are poor, does not seem valid.

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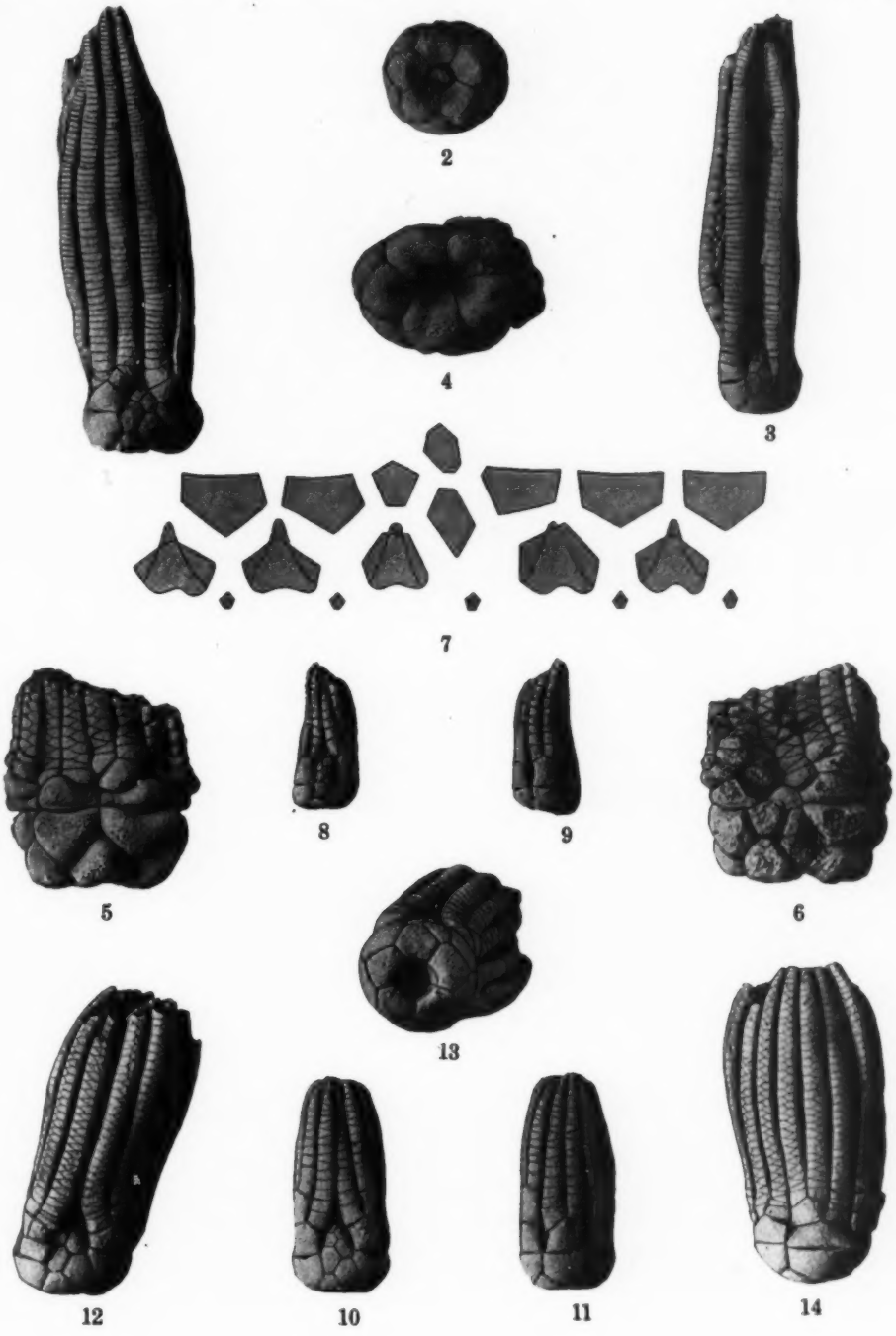
EXPLANATION OF PLATE 84

FIGS. *1, 2—Phanocrinus formosus* (Worthen). *1*, Posterior view; *2*, basal view, ×1. (p. 603)

3—Phanocrinus gracilis (Wetherby). Posterior view, ×1. (p. 604)

4–7—Eupachycrinus quatuordecimbrachialis (Lyon). *4*, Basal view; *5*, view of left anterior interradius; *6*, posterior view; *7*, plate diagram, ×1. (p. 599)

8–14—Eupachycrinus spartarius S. A. Miller. *8*, *9*, Posterior and anterior views of very young specimen, ×2. *10*, *11*, Posterior and anterior views of somewhat older specimen, ×2. *12–14*, Posterior, basal, and anterior views of adult specimen, ×1. (p. 601)



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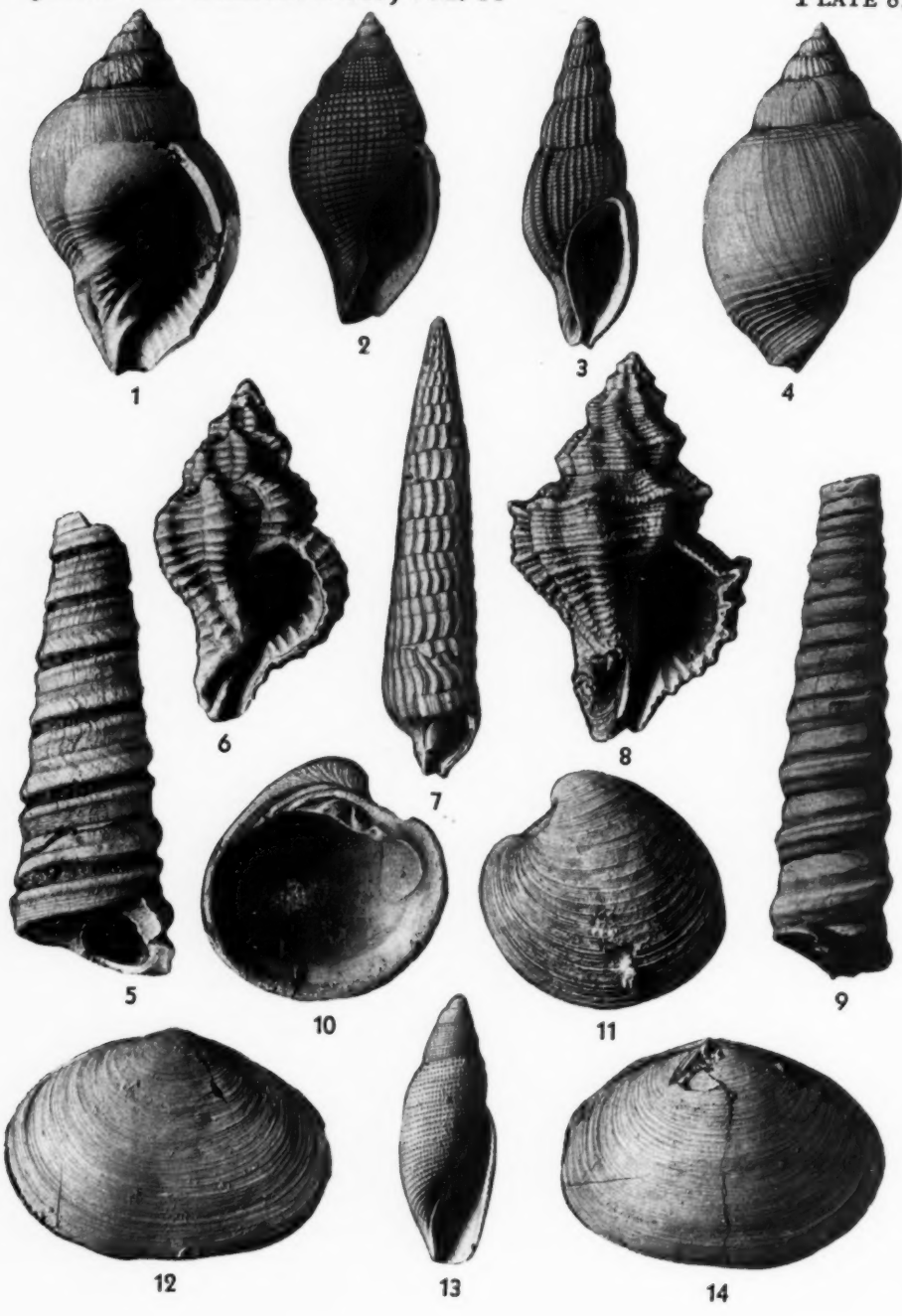

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Explanation of Plate 85 is on page 608.

JOURNAL OF PALEONTOLOGY, VOL. 11, NO. 7, PP. 608–612, PL. 85, OCTOBER, 1937

NEW MOLLUSKS FROM THE CHOCTAWHATCHEE FORMATION OF FLORIDA

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ABSTRACT

This paper describes seven new species and one new subspecies of mollusks from the Miocene Choctawhatchee formation and lists newly discovered occurrences of several other species.

Collections from the Miocene Choctawhatchee formation made since the publication of my three papers on its fauna (4, 5, 6) have yielded seven undescribed species and one new subspecies of mollusks, which are described herein. Several other species have been found at places from which they had not previously been reported, as follows:

In the *Ecphora* zone, *Fusinus dalli* was found in the lower bed of the upper Miocene at Jackson Bluff, Leon County, Florida, and *Turritella* cf. *T. terstriata* Rogers was found 1 mile northwest of Clarksville, Calhoun County. The latter species occurs also in zone 1 of the Yorktown formation in Virginia. In the *Cancellaria* zone, *Rictaxis* cf. *R. oryza* (Gabb), *Clathrodrillia? anteaphanitoma* Mansfield, *Solenosteira vaughani* Dall, and *Macoma hosfordensis* Mansfield were found in a borrow pit in the upper bed at Jackson Bluff.

SYSTEMATIC DESCRIPTIONS

RICTAXIS cf. R. ORYZA (Gabb)
Plate 85, figure 13

Shell small, very slender, mainly spirally sculptured; spire about one-fifth total length of shell, consisting of four whorls. Nucleus consisting of one smooth whorl with an immersed tip. Suture distinct and appressed. Postnuclear whorls weakly inflated, beveled above and below and sculptured with narrow, punctate incised lines, which separate flat bands (11 on the penultimate whorl), which are wider than the interspaces. Aperture long, narrower above. Outer lip thin. Columella slightly arched and bear-

EXPLANATION OF PLATE 85

FIGS. *1, 4—Cancellaria (Cancellaria) macneili* Mansfield, n. sp., holotype, ×1+. (p. 609)
2—Pisania (Celatoconus) harveyensis Mansfield, n. sp., holotype, ×2⅓. (p. 610)
3—Colubraria leona Mansfield, n. sp., holotype, ×3+. (p. 610)
5—Turritella cf. *T. terstriata* Rogers, figured specimen, ×3+, from the *Ecphora* zone, 1 mile northwest of Clarksville, Calhoun County, Florida; height 20 mm.; U. S. Nat. Mus. 496428; compare with fig. 9. ×2½+. (p. 608)
6—Muricidea clarksvillensis Mansfield, n. sp., holotype, ×1½+. (p. 610)
7—Terebra blakei Mansfield, n. sp., holotype, ×1½+. (p. 609)
8—Coralliophila leonensis Mansfield, n. sp., holotype, ×2½. (p. 611)
9—Turritella terstriata Rogers, figured specimen, ×1½+, from zone 1, Yorktown formation, at station 11783, Watkins mill, King and Queen County, Virginia, from bed above a basal conglomerate. (p. 608)
10, 11—Antigona clarksvillensis Mansfield, n. sp., holotype, ×¾+. (p. 612)
12, 14—Cochlodesma leana floridana Mansfield, n. subsp., holotype, ×¾+. (p. 611)
13—Rictaxis cf. *R. oryza* (Gabb), figured specimen, ×5½−. (p. 608)

ing on its upper part a single oblique and prominent plication.

Dimensions of figured specimen (U. S. Nat. Mus. 496422): length, 7 mm.; diameter, 2.5 mm.; length of aperture, 4 mm.

Occurrence.—Borrow pit, Jackson Bluff, Leon County, Florida. Collected by S. F. Blake. Upper Miocene, *Cancellaria* zone.

Comparisons.—This specimen is smaller and slimmer than "*Acteon*" *myakkanus* Dall, a Pliocene species. It agrees with the illustration of the holotype of *Rictaxis oryza* (Gabb) as figured by H. A. Pilsbry in the Proceedings of the Academy of Natural Sciences of Philadelphia, part 2, plate 23, figure 12, 1921 (1922). *Rictaxis oryza*, which was collected in Santo Domingo, was described by W. M. Gabb under a new genus, "*Actaeonidea*," in the Transactions of the American Philosophical Society, new series, volume 15, page 245, 1873. It is much slimmer than *Rictaxis punctocoelata* Carpenter, the genotype of *Rictaxis*, but has a similar columellar fold.

TEREBRA BLAKEI Mansfield, n. sp.
Plate 85, figure 7

Shell of moderate size, solid, strongly axially sculptured, consisting of 16 remaining whorls (tip decollated). Subsutural band about one-third length of whorl and constricted below by a narrow sulcus. Axial sculpture of strong rounded curved ribs, 20 on the penultimate whorl. Spiral sculpture obscure or wanting on the spire whorls but on last whorl the lower third contains low narrow bands. Columella with one plication.

Dimensions of holotype (U. S. Nat. Mus. 496423): Length, 40 mm.; diameter, 8.5 mm.

Occurrence.—Borrow pit in the upper bed at Jackson Bluff, Leon County, Florida, upper Miocene, *Cancellaria* zone (holotype); the Muldrow place, 5 miles southeast of Mayesville, South Carolina (U. S. Geol. Survey Station 4000), Miocene, Duplin marl.

Remarks.—*Terebra blakei* is represented by one fairly well preserved specimen, the holotype, collected in 1936 by Dr. S. F. Blake of the U. S. Department of Agriculture, in whose honor the species is named, and a fragment collected at the same place in 1927 by the Florida State Geological Survey. Most of the specimens from South Carolina have faint spiral bands on the lower half of each whorl.

CANCELLARIA (CANCELLARIA) MACNEILI
Mansfield, n. sp.
Plate 85, figures 1, 4

Shell rather large, stout, thin and consisting of six rapidly expanding whorls. Suture loosely appressed. Whorls rounded below the suture. Nucleus corroded. First two to three postnuclear whorls slightly corroded but showing feeble axials crossing them; following whorls devoid of axials. Shoulders of postnuclear whorls ornamented with three or four rounded spiral cords; the area below without distinct spirals, except on the base and canal of the last whorl, which has about ten spiral cords, which are narrower than the interspaces. Parietal callus thin. Margin of outer lip broken off. Siphonal fasciole well developed. Columella bearing two oblique folds—the posterior one being the stronger—above the raised inner border of the canal. Canal short.

Dimensions of holotype (U. S. Nat. Mus. 496440): Length, 42.5 mm.; diameter, 25 mm.

Occurrence.—Station 14006, Vaughan Creek, a short distance below the head of a shallow gorge that cuts through the marl, Walton County, Florida. Collected by W. C. Mansfield and F. S. MacNeil in 1936.

Comparisons.—The absence of sculpture on most of the shell of *Cancellaria macneili* and the arrangement of its columellar plications suggest a close relationship to *C. laevescens* Guppy, a Miocene species occurring in the Bowden marl of Jamaica. However, the latter

species has stronger and more persistent axials and a flatter area below the suture than the Florida species.

PISANIA (CELATOCONUS) HARVEYENSIS
Mansfield, n. sp.
Plate 85, figure 2

Shell small, fragile, subfusiform, spiral sculpture stronger than axial and consisting of 5½ to 6 weakly turreted and moderately inflated whorls—the last whorl comprising about five-sevenths of the length of the shell. The nucleus, consisting of 1½ to 2 whorls, corroded but apparently smooth. Spiral sculpture of about 7 closely spaced, flattish and narrow bands beginning on the following whorl. The succeeding whorls are rather strongly sculptured with straplike bands (about 7 on the posterior two whorls), wider than interspaces and rippled by narrow riblets, which form small squarish, slightly elevated nodules at the intersection with the spirals. Suture appressed and distinct. Outer lip gently arched and bearing on the inner margin 17 short, rounded, entering denticles. Body wall and columella provided with a thin wash of callus. Canal wide and short.

Dimensions of holotype (U. S. Nat. Mus. 496302): Length, 18 mm.; greatest diameter, 8.6 mm.; length of aperture, 10 mm.

Occurrence.—Harveys Creek about half a mile above an abandoned mill, Leon County, Florida, upper Miocene, *Cancellaria* zone. Collected by the Florida State Geological Survey.

Comparisons.—*Pisania* (*Celatoconus*) *harveyensis* is closely related to P. (*Celatoconus*) *nux* Dall (3), a species collected from the "Miocene" of the Cape Fear River, North Carolina, but differs from the latter species in having more closely spaced spirals without any indication of intercalary threads.

COLUBRARIA LEONA Mansfield, n. sp.
Plate 85, figure 3

Shell small, slender, with a spire nearly equal in length to its body whorl, with axial and spiral sculpture of about the same strength and consisting of 6½ weakly inflated and slightly shouldered whorls. Suture distinct but not very deep. Nucleus smooth, naticoid and consisting of 2 rapidly expanding whorls. First postnuclear whorl ornamented with 7 narrow straplike spirals (the one at the periphery being a little stronger than the others) and nearly vertical axials, forming at their intersection with the spirals small nodules. On the penultimate whorl the axials increase to 22 in number, and weaker spiral bands intercalate the primary ones. Aside from these, there are 3 to 4 very fine spiral threadlets, which become more distinct on the last whorl, between the secondary spiral bands. About 2 varices ornament each whorl. Aperture long and narrow. Outer lip thin, inner margin with a few short entering denticles. Body wall and columella provided with a thin, smooth, marginally elevated plication. Canal short and recurved.

Dimensions of holotype (U. S. Nat. Mus. 496290): Length, 14 mm.; greatest diameter, 5 mm.; length of aperture, 6 mm.

Occurrence.—Borrow pit in the highest bed at Jackson Bluff, Leon County, Florida, upper Miocene, *Cancellaria* zone, collected by the Florida State Geological Survey (type). Natural well and Magnolia, North Carolina, upper Miocene, Duplin marl.

Comparisons.—*Colubraria leona* is most closely related to *C. lanceolata* Menke, a Pliocene and Recent species, but differs from the latter in having a slimmer shell and being marked with more and weaker axials.

MURICIDEA CLARKSVILLENSIS
Mansfield, n. sp.
Plate 85, figure 6

Shell of moderate size; solid; spire about one-third length of shell; axial sculpture stronger than spiral; consisting of 5 whorls, nucleus decollated. Whorls rounded, weakly tabulated in front of the rather deep suture and rapidly and uni-

formly expanding. Spiral sculpture consisting of rather strong primary threads (13 on body whorl and canal) overrunning axials and interspaces and usually of a secondary intermediate threadlet. Ribs 6, extending from suture to suture on the spire whorls and to the end of the canal on the body whorl. Aperture axially ovate. Outer lip within provided with 8 widely spaced spiral lirations. Inner lip with a thin callus and bearing on its anterior third 3 lirations. Canal rather short and recurved; the raised margin of the canal and the siphonal fasciole separated by a small chink.

Dimensions of holotype (U. S. Nat. Mus. 496424): Length, 30 mm.; diameter, 17 mm.

Occurrence.—Fourmile Creek half a mile northwest of Clarksville, Calhoun County, Florida, upper Miocene, *Ecphora* zone. Collected by the Florida State Geological Survey.

Comparisons.—*Muricidea clarksvillensis* apparently is related to *Muricidea? alaquaensis* Mansfield, a species described from the *Arca* zone, the upper part of the middle Miocene at Vaughan Creek, Walton County, Florida, but it is much larger than the latter species, has a less tabulated shoulder, and lacks the tertiary threadlets.

Coralliophila leonensis
Mansfield, n. sp.
Plate 85, figure 8

Shell of moderate size, subbiconic, spire about one-third length of shell, both axially and spirally sculptured, and consisting of six whorls. Nucleus small, smooth, naticoid, with immersed tip. Suture deep and appressed. Following whorls strongly angulated medially, the projection at the periphery gradually becoming stronger forward and on the last whorl forming a thin, lamellalike projection. Axial sculpture consisting of strong, rounded ribs (8 on the body whorl), which extend from suture to suture on the spire whorls and to the base on the last whorl. Spiral sculpture of imbricated lines, about 10 on the spire whorls, 5 lying above and 5 below the periphery. Primary, secondary, and tertiary lines alternating in size on the body whorls below the periphery. About 8 rather strong cords on the canal. Aperture ovate; inner border of outer lip crenulated in conformity with exterior sculpture; columella provided with a callus behind which is a small chink. Fasciole strong and plicated. Canal short and recurved.

Dimensions of holotype, the only specimen (U. S. Nat. Mus. 496425): Length, 22.8 mm.; diameter, 13.7 mm.

Occurrence.—Borrow pit in the highest bed at Jackson Bluff, Leon County, Florida. Upper Miocene, *Cancellaria* zone. Collected by the Florida State Geological Survey.

Comparisons.—*Coralliophila leonensis* is most closely allied to *C. bracteata* Brocchi, a species living from Hatteras to Key West.

Cochlodesma leana floridana
Mansfield, n. subsp.
Plate 85, figures 12, 14

Shell large, thin and fragile, and nearly equivalve. Right valve more inflated than left, surface broadly rounded; posterior dorsal region more steeply inclined than anterior region. Left valve depressed medially in the lower half of the shell and with a steeper slope in the posterior dorsal region than in the anterior. Surface nearly smooth except for concentric growth structures.

Dimensions of holotype, valves intact (U. S. Nat. Mus. 496426): Length, 58 mm.; height, 40 mm.; thickness, 15.5 mm.

Occurrence.—Lower part of the upper Miocene bed, *Ecphora* zone, at Jackson Bluff, Leon County, Florida, collected by the Florida State Geological Survey.

Comparisons.—The shell of the new subspecies has the outline of that of *Cochlodesma leana* (Conrad), but it is about twice the size of the living species.

Cochlodesma antiqua (Conrad) (1), a species reported from the upper Miocene at Yorktown, Virginia, is more ovate than the new subspecies here described but apparently very closely allied to it.

Dall (2) reports the geographical range of *Cochlodesma leana* (Conrad) to be Nova Scotia to Hatteras, but it is more abundant in the northern part of this range than in the southern.

The presence of this genus in the *Ecphora* zone of the Choctawhatchee formation gives additional proof that the formation was deposited in cold water.

ANTIGONA CLARKSVILLENSIS
Mansfield, n. sp.
Plate 85, figures 10, 11

Shell small, rounded, strongly inflated, and subequilateral. Anterior margin slightly more produced than posterior. Beak high, full, and prosogyrate. Lunule large and well defined. Sculpture consisting of upright concentric lamellae. One (sometimes two) stronger lamella in the midst of 4 or 5 weaker ones. Inner margin crenulated. A minute anterior tooth, characteristic of the genus, is present. Other teeth normal to the genus.

Dimensions of holotype, left valve (U. S. Nat. Mus. 496427): Length, 43.5 mm.; height, 42 mm.; convexity, 18.2 mm.

Occurrence.—Fourmile Creek half a mile northwest of Clarksville, Calhoun County, Florida, upper Miocene, *Ecphora* zone. Collected by the Florida State Geological Survey. The holotype is the only specimen known.

Comparisons.—*Antigona clarksvillensis* may be an ancestral form of *A. rugatina* (Heilprin), a Pliocene to Recent species. Its shell is smaller, thicker, and relatively more inflated than that of the later species, and its beak is more protruding.

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JOURNAL OF PALEONTOLOGY, VOL. 11, NO. 7, PP. 613–619, 7 TEXT FIGS., OCTOBER, 1937

NEW GENERA AND SPECIES OF TETRAPODS FROM THE KARROO BEDS OF SOUTH AFRICA

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ABSTRACT

This paper describes three new species of reptiles, including one referred to a new genus, *Youngoides*, and one new rachitomous amphibian, for which the new genus *Rhinesuchoides* is erected.

Among the recently prepared specimens in the Walker Museum, University of Chicago, are several new forms from the Karroo beds of South Africa. The present paper is designed to figure and give brief, preliminary accounts of these specimens.

SCYMNOGNATHUS MAJOR
Olson and Broom, n. sp.
Text figures 1, 2

This large gorgonopsian, represented by a well-preserved skull and part of the lower jaws, is closely allied to *Scymnognathus whaitsi* Broom. Distinct differences in the proportions of the skull and in the shapes of the bones make it necessary to refer it to a new species, *Scymnognathus major*, so named because of the exceptional size of the animal. The skull is slightly longer than 340 mm. As it is somewhat crushed, it is impossible to determine the original width. The maximum height, measured vertically from the canine, is 110 mm.

The upper dental formula agrees with that of *S. whaitsi*, being i.5, c.1, m.4.

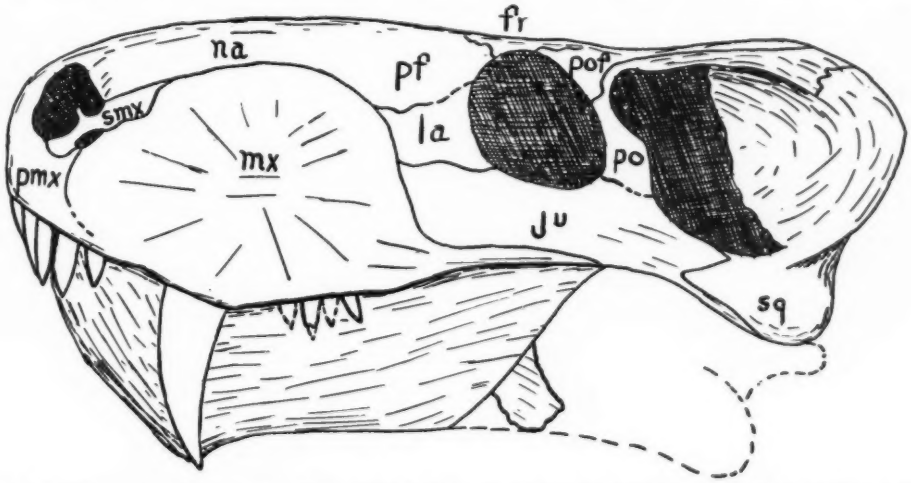

FIG. 1—*Scymnognathus major* Olson and Broom, n. sp. Lateral aspect of skull. fr, frontal; ju, jugal; la, lacrimal; mx, maxillary; na, nasal; pf, prefrontal; pmx, premaxillary; po, postorbital; pof, postfrontal; smx, septomaxillary; sq, squamosal, ×⅓.

Two of the molars are present and two are represented by alveoli. The length of the incisor series is 46 mm. and that of the molar series is 36.5 mm. The canine is 69 mm. in length and has a basal diameter of 23 mm.

The proportions of the skull are different from those of *S. whaitsi*. The ratio of maximum length to maximum height in the latter is about 4:1 whereas in the new species it is about 3:1. Other differences, such as the shape of the orbits, temporal fossae, and the bones of the lateral surfaces, are apparent in figure 1.

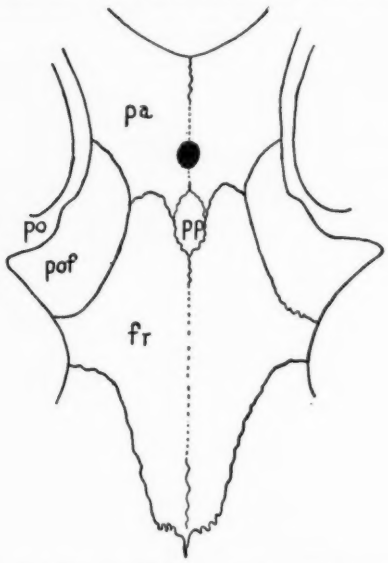

FIG. 2—*Scymnognathus major* Olson and Broom, n. sp. Dorsal aspect of parietal and frontal region. pa, parietal; pp, preparietal. Other lettering as in figure 1.

The nature of the frontal region is shown in figure 2. In contrast to *S. whaitsi*, the pineal opening is relatively large. The postfrontals make up a larger portion of the orbital margin than in *S. whaitsi* and the prefrontals are proportionately larger. Other minor differences are apparent in the figure.

The lower jaw is similar to that in *S. whaitsi*. Only the dentary, a deep, massive bone, is well preserved.

Type.—University of Chicago 1513.

Occurrence.—*Endothiodon* zone. Brakwater farm northeast of Murraysburg, west of Victoria road, and three-quarters of a mile south of river crossing.

YOUNGOIDES ROMERI Olson and Broom, n. gen. and sp.
Text figure 3

Youngina capensis Broom. OLSON, *1935*, Jour. Geology, vol. 44, pp. 523–533, text fig. 1.

Further development of the dorsal and lateral surfaces and the outer surface of the lower jaw of the specimen described by Olson in 1935 as *Youngina capensis* Broom indicates that it belongs to a new genus closely allied to *Youngina*. The skull differs from that of *Youngina* in the structure of the temporal region, the size and shape of various bones, and the proportions of the lower jaws. There are also slight differences in the size and proportions of the skull, but these alone are not sufficient to exclude the specimen from the genus *Youngina*.

The lower temporal fenestra of *Youngoides romeri* is relatively small, being only about half as wide as the orbit, whereas this opening in *Youngina* is nearly as large as the orbit. The opening in *Youngoides* is roughly triangular and that in *Youngina* is more or less rectangular. The parietal region of the new genus is narrow. As in *Youngina*, the parietal bones are extended back between the tabulars and supraoccipital, but in *Youngoides* the tabulars clasp the parietals distally, much as in *Varanus*.

The dentition of the two forms is similar. In the new genus, however, there are 23 upper teeth, a few more than recorded in *Youngina*.

The anterior part of the lower jaw of *Youngoides* is very slender and rodlike, differing markedly from that in *Youngina*. The posterior portion is deep and similar to that in *Youngina*, but the articular appears to be less well developed in *Youngoides*.

Type.—University of Chicago 1528.

Occurrence.—Lower *Cistecephalus* zone, Toverwater farm, southeast of Murraysburg.

STRUTHIOCEPHALUS MILLERI
Olson and Broom, n. sp.
Text figure 4

Struthiocephalus milleri is based on a well-preserved skull. Principal measurements are as follows: Maximum length, 480 mm.; maximum width, 300 mm.; intertemporal width, 115 mm.; interorbital width, 130 mm.

forward, and the strong development of the frontal boss.

S. milleri differs from *Keratocephalus moloch* von Huene in that the parietal region is much narrower and the snout longer. The nostrils are farther forward than in either *S. rheideri* or *S. whaitsi* Haughton.

Type.—University of Chicago 1512.

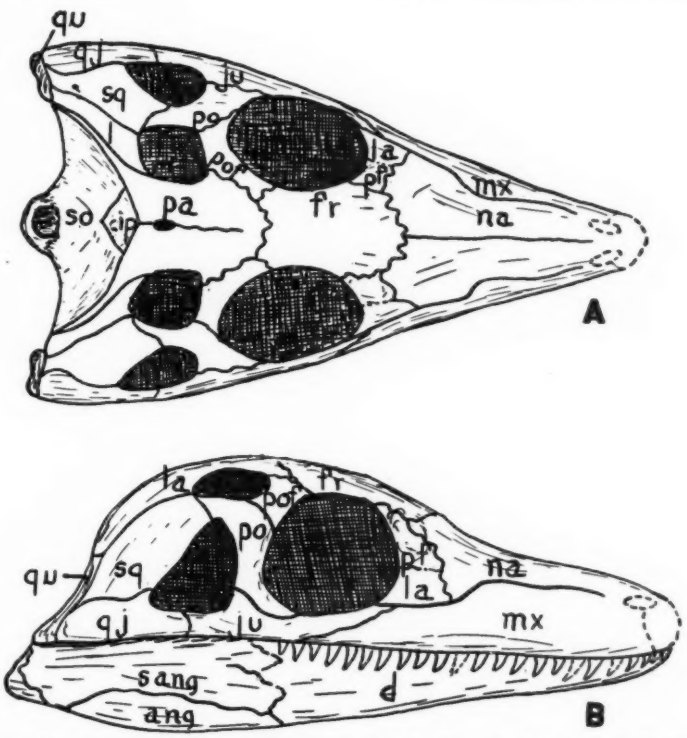

FIG. 3—*Youngoides romeri* Olson and Broom, n. sp. A, Dorsal aspect of skull. B, Lateral aspect of skull and lower jaw. ang, angular; d, dentary; ip, interparietal; pa, parietal; qj, quadratojugal; qu, quadrate; sang, surangular; so, supraoccipital. Other lettering as in preceding figures, ×1½.

The proportions of this skull, the location of the various fossae, and the very pronounced frontal boss make it necessary to refer this specimen to a new species. Unfortunately, as in many other specimens from this locality, it is impossible to make out many of the sutures. The form is allied to *S. rheideri* Broom but is distinguished from it by the very large pineal opening, placed rather far

Occurrence.—*Tapinocephalus* zone, ¼ mile southwest of Stinkfontein.

PAREIASAURUS PINNATUS
Olson and Broom, n. sp.
Text figure 5

The type is a small, apparently adult specimen of *Pareiasaurus* consisting of upper and lower jaws, a part of the skull, several vertebrae, a pelvis, and part of

the hind limb. It is allied to *P. pulcher* Broom and *P. russouwi* Seeley but is distinctly different from either species.

42 mm.; 5th, 6th, 7th, and 8th, 36 mm.; 10th, 11th, 12th, and 13th, 36 mm.

The first upper tooth has 13 rather

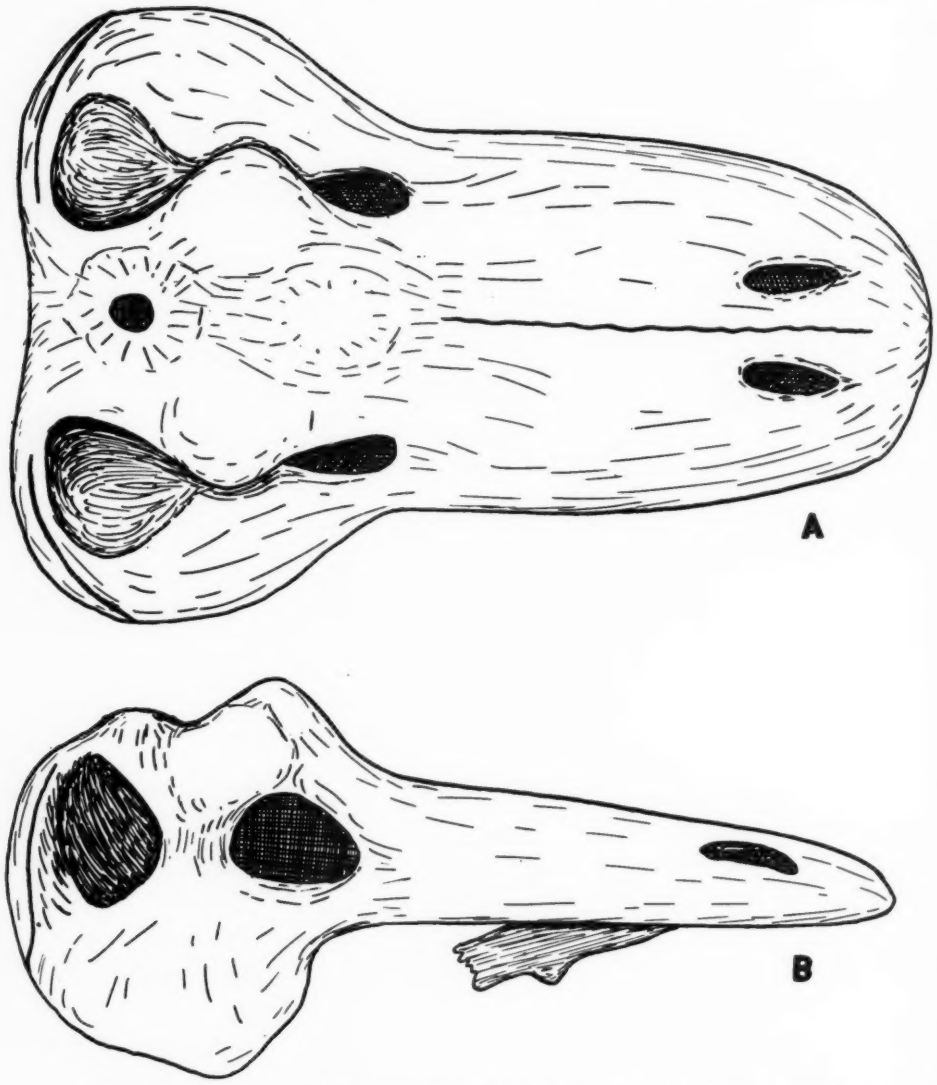

FIG. 4—*Struthiocephalus milleri* Olson and Broom, n. sp. A, Dorsal aspect of skull. B, Lateral aspect of skull, $\times\frac{1}{4}$.

In the upper tooth row there are 16 teeth, which measure about 145 mm. Other measurements of the upper teeth are as follows: 1st, 2d, 3d, and 4th, small cusps, and its outer side is markedly convex. In all the other uppers in which the cusps can be counted the same number, 13, is found to be present. The

most anterior and most posterior cusp of each tooth is very large. In this respect the species agrees with *P. pulcher*, but in the latter the first tooth has but 9 cusps.

There are 16 lower teeth, and the length of the tooth row is about 140 mm. Other measurements are as follows: 5th, 6th, 7th, and 8th, 49 mm.; 11th, 12th, and 13th, 29 mm. The number of cusps on the lower teeth cannot be determined because they are too badly damaged.

The mandible differs from that of *P. russouwi* in being very short and having the midpart much deeper than the front. Also the cusps of the lower teeth do not appear to extend as far down the sides in the new species as in *P. russouwi*. The ventral process of the jaw is well developed, but it is much shorter than the process in *P. pulcher*.

The remainder of the skeleton, though well preserved, possesses little of diagnostic value and need not be described in this paper.

Type.—University of Chicago 1562.

Occurrence.—*Endothiodon* zone, Wagenaar's Kraal.

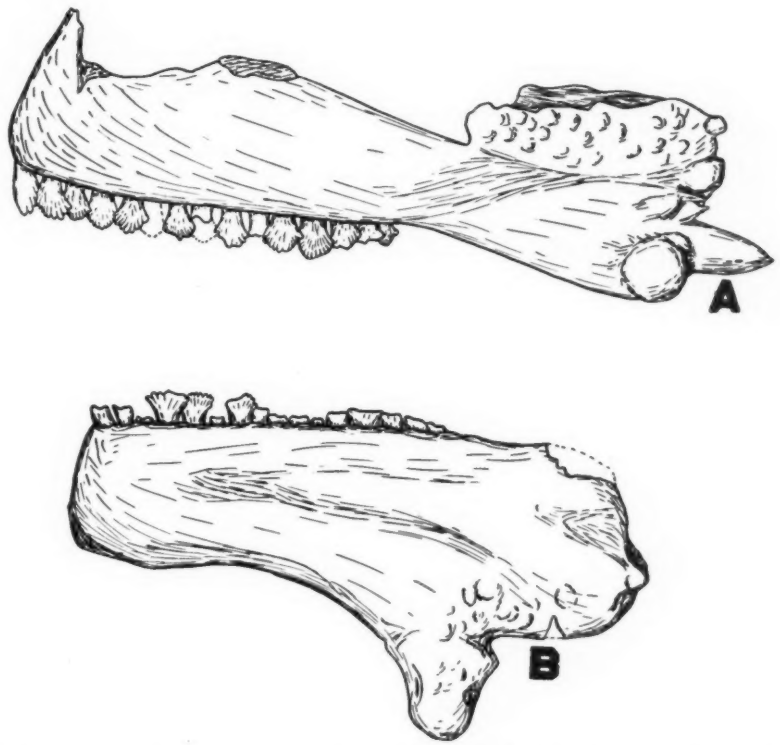

FIG. 5—*Pareiasaurus pinnatus* Olson and Broom, n. sp. A, lateral aspect of upper jaw and part of skull. B, Lateral aspect of lower jaw, $\times\frac{1}{3}$.

RHINESUCHOIDES TENUICEPS
Olson and Broom, n. gen. and sp.

Text figures 6, 7

This new species of the rachitomous amphibians is represented by a skull and the left ramus of the lower jaw. It is allied to *Rhinesuchus* but is so different in shape and proportion that it must be placed in a new genus.

The skull is exceptionally long and narrow. The ratio of width to length is about 1:2, whereas in *Rhinesuchus whaitsi* it is about 5:6 and in *Rhinesuchus senekalensis* it is about 4:5. Principal measurements of *Rhinesuchoides tenuiceps* are as follows: Maximum length, 360 mm.; maximum width, 195 mm.; interorbital width, 48 mm.; internasal width, 37 mm.; intertemporal width, 98 mm.; back of nares to front of orbit, 165 mm.; snout to front of orbit, 195 mm. A comparison of these measurements with those of allied forms shows the striking differences in the proportions of the skulls.

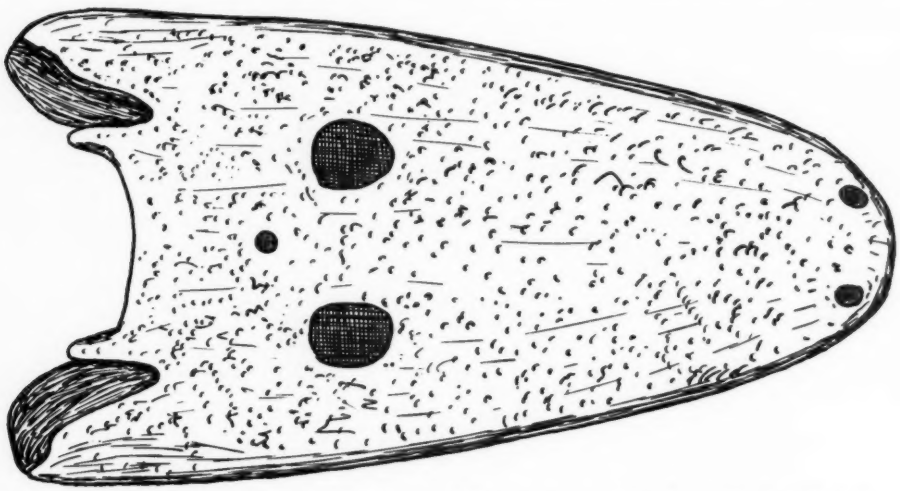

FIG. 6—*Rhinesuchoides tenuiceps* Olson and Broom, n. sp. Dorsal aspect of skull, ×⅓.

The palate is rather badly damaged. So far as it is possible to tell, the structure is not greatly different from that of *Rhinesuchus whaitsi* except for proportional differences reflecting the shape of the skull. Teeth are strongly developed

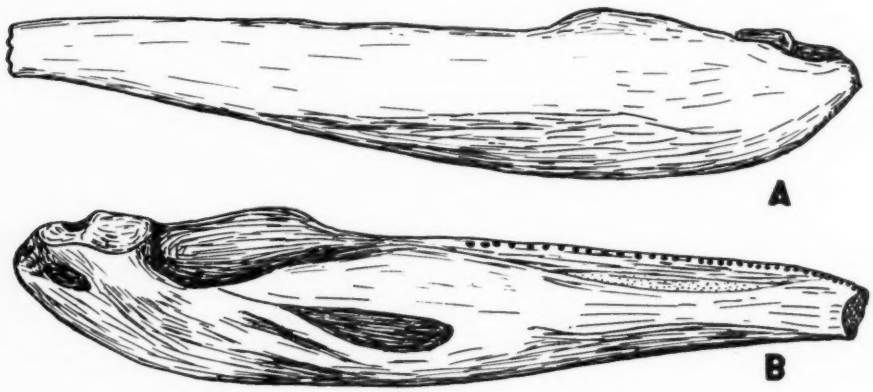

FIG. 7—*Rhinesuchoides tenuiceps* Olson and Broom, n. sp. A, Lateral aspect of lower jaw. B, Medial aspect of lower jaw, ×⅓.

along the margin of the upper jaw and are present, much as in *Rhinesuchus*, on the palate.

The structure of the lower jaw is clear from figure 7. The ramus is long and slender. Teeth are present along the margin and are well developed on the coronoids. It is impossible to make out the sutures between the bones, but their positions are fairly well indicated by the various structures of the jaw. The arrangement of the bones is similar to that in *Rhinesuchus*.

Type.—University of Chicago, 1519.

Occurrence.—*Tapinocephalus* zone, 2 miles east of Stinkfontein.

NOTE: The manuscript of this paper was received by the editor June 5, 1937.

JOURNAL OF PALEONTOLOGY, VOL. 11, NO. 7, PP. 620–623, 1 TEXT FIG., OCTOBER, 1937

TAENIASTER IN PENNSYLVANIA

BRADFORD WILLARD
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ABSTRACT

A new species of aulurid stelleroid, the first to be found in the Upper Ordovician Martinsburg shale in Pennsylvania, is here described and named *Taeniaster maximus*. *Taeniaster* has been recorded from Canada, New York, and Ohio in rocks of Trenton and Richmond ages. The specimen here described came from northern Cumberland County, Pennsylvania, and is of Eden age or slightly older.

A brief discussion of the geologic setting of the *Taeniaster* described in this paper is appropriate because of recently awakened interest in Pennsylvania in the Ordovician shales from which the fossil comes. During the 1936 field season, the author began a study of the Martinsburg "shale" ("Hudson River" of early reports) in Pennsylvania. Particular attention was devoted to the faunas. These studies have been carried from the Maryland-Pennsylvania line northeastward and eastward to the valley of Swatara Creek about 25 miles east of Harrisburg, where the season's work terminated save for reconnaissance farther east.

The Martinsburg is distributed as a continuous broad band across the southeast-central part of Pennsylvania, and it or its near equal, the Reedsville, is also represented in isolated areas in the central part of the State. It has been much discussed. Estimates range from two thousand to many thousand feet. The tremendous thicknesses sometimes reported should be closely scrutinized and seriously questioned, for key beds by which the complex structures can be unravelled and the precise or even closely approximate thickness made known are almost unrecorded.

The designation "shale" is a misnomer, for the Martinsburg includes many kinds of rock. Much of the Martinsburg west of the Susquehanna Valley is dark shale, but sandstone makes up as much as 40 percent of the total thickness. East of that valley, besides the sandstones, a thick succession of red beds associated with local lenses of platy limestone is a conspicuous feature. Conglomerate is occasionally encountered along with other minor lithologic variations. Farther east, in the Lehigh and Delaware valleys, the Martinsburg becomes slate, still with a large proportion of sandy beds. When its stratigraphy becomes better known, the name Martinsburg may be raised to the status of a group.

The age of the Martinsburg awaits final definition. Its highest beds have been assigned to the Eden or even Maysville, and faunas of Pulaski age have been reported. As its base is drawn at the top of the Chambersburg limestone where that is present (mostly west of the Susquehanna

River), the lower part is of early Trenton age. Farther east the Martinsburg rests unconformably upon the Jacksonburg limestone. In these regions the lowest beds should be somewhat younger than those to the west.

Fossils are rare in the slate regions, but westward grow more plentiful. The upper Martinsburg is highly fossiliferous in north-central Berks County and on Swatara Creek. Organic remains are plentiful near the top from north-central Cumberland County southwestward to Maryland. In lower strata fossils are usually rare, particularly east of the Susquehanna. The lower one-half to two-thirds is usually almost barren. At the base, principally in the more western sections, rather numerous fossils are again found as the Martinsburg grades down into the Chambersburg limestone. The Martinsburg has produced very few Stelleroidea, which are rare fossils in the Paleozoic rocks. So far as known to the writer, the specimen here described is the first stelleroid of the subclass Auluroidea to be recorded from the upper Ordovician Martinsburg "shale" of Pennsylvania.

DESCRIPTION OF SPECIES

Class STELLEROIDEA
Subclass AULUROIDEA
Order LYSOPHIURAE Gregory
Family PROTASTERIDAE Miller

Genus TAENIASTER Billings, 1858

Schuchert (3) described *Taeniaster* as follows:

> Generic characters—Body deeply stellate; no disk [there is a disk] or marginal plates; rays long, slender, flexible, and covered with small spines; two rows of large ambulacral pores; adambulacral plates elongated and sloping outward so that they partly overlap each other; ambulacral ossicles contracted in the middle, dilated at each end. Generic name from *taenia*, a riband.

After discussing the above statement and subsequent suggested modifications by authors, Schuchert continues:

> . . . the writer restudied the genotype of *Taeniaster* at Ottawa (two specimens, No. 1404, the originals of figures 3a–3b of Billings' Plate X). There can be no doubt that we have here a genuine lysophiurid. There is a small disk present in the individual figured as 3a and 3b, but it is not one with a round outline, as in typical ophiurids, but is concave along the margin between the rays. Actually this disk is abundantly covered with prominent but slender spines.
>
> The ambulacrals are distinctly alternate throughout the rays and appear as in the sketch presented on page 218; this condition is not due to distortion or other causes. The side plates are narrow, and each bears three spines (see fig. 17B); toward the mouth the two columns diverge far more than one would assume from the original figure, and in consequence there are long and slender syngnaths and not the asterid-like mouthpieces figured in the illustration.

TAENIASTER MAXIMUS Willard, n. sp.

Figure 1

Our specimen has an estimated minimum diameter of 30 mm. The five flat flexible rays, which have all lost their tips, are attached to a small disk 6.5 mm. in diameter. The disk is not circular but is indented at the axils. The abactinal surface is unknown; dorsal spines protrude along ray margins. The ambulacrals (ambulacral ossicles), which alternate in the best preserved least distorted areas, are triangular or conical bodies whose staggered bases produce zigzag ambulacral grooves along the midline of the ventral surfaces of the rays. The adambulacrals (side plates) are shaped

like thick commas, the sharp ends pointing radially away from the disk and parallel to the sides of the rays. Their bases alternate with the ambulacrals. Although spines are doubtfully preserved on the adambulacrals, some show a slight rugosity of their distal extremities.

FIG. 1—*Taeniaster maximus* Willard, holotype, a natural cast of the ventral surface. ×3.

About the mouth the syngnaths are relatively long slender rods extending nearly to the center of the disk, where adjacent pairs from neighboring arms coalesce as straight-sided U's, the bases directed centrally. The intervening areas between the pairs of syngnaths are filled in the natural cast with large, lozenge-shaped bodies of matrix like those of *T. spinosus* shown in Billings' figure 3b of the type specimen (1).

The new species, *T. maximus*, is based on a single incomplete but otherwise fairly well preserved natural cast of the ventral surface. The tips of all five rays are missing, and there has been some movement or distortion of parts. Fortunately, this is so slight that the plates show relatively little displacement. The matrix, very finely arenaceous shale, dark when fresh, weathering light brown or buff, has preserved a moderately accurate record of details.

Comparison.—*Taeniaster maximus* Willard most nearly resembles *T. spinosus* (Billings) but differs in its greater size, having at least twice the diameter of the latter. The adambulacrals are distinctly comma-shaped, not slender and slightly curved like the rods of *T. spinosus*. *T. maximus* is also larger than *T. cylindricus* (Billings), and the rays are flatter and stockier. It differs from *T. schohariae* Ruedemann, which is smaller and has more attenuated arms, and the ambulacrals and adambulacrals differ in form and arrangement, although both species possess zigzag ambulacral grooves. The ambulacral plates of *T. maximus* are distinguished from those of *T. elegans* Miller by their form, and the arms of the latter are reported to be nearly cylindrical. Finally, *T. maximus* may be at once distinguished from *T. meafordensis* Foerste, not only by its greater size but by the large disk of the latter, which extends well out beyond the axillary regions. Foerste (2) mentions *T. miamiensis* (Miller), cited by Schuchert as *Alepidaster miamiensis* (Miller). The author has not had access to the type specimen, but the original description indicates that, like *T. meafordensis*, the disk is proportionately considerably larger than in *T. maximus*.

Occurrence.—The specimen was collected from the upper Martinsburg "shale" at Colonel Demming State Camp, Cumberland County, Pennsylvania, off State Highway 233 south of Doubling Gap in a small quarry at the juncture of two roads leading from the camp to the main highway. The few associated fossils are "crinoid" columnals, a fragmentary linguloid, part of a strophomenoid brachiopod (*Strophomena halli* (Miller)?), and a few other fragments. The horizon is several hundred feet below the abundant Eden fauna usually found near the top of the Martinsburg in this part of Pennsylvania; exactly how far below cannot be ascertained because of folding and large concealed intervals.

Type.—The holotype is in the Ordovician collections of the Pennsylvania Topographic and Geologic Survey Harrisburg, Pa.

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NOTE: This paper, which was presented before the Paleontological Society December 29, 1936 is published with the permission of the State Geologist of Pennsylvania. The manuscript was received by the editor Feb. uary 24, 1937.

PALEONTOLOGICAL NOTE

A MIOCENE CLAM THAT LIVED IN A BARNACLE SHELL

JOHN B. BUCK
Johns Hopkins University, Baltimore, Maryland

In September, 1935, a large barnacle that contained a small bivalve mollusk completely filling its cavity was found in the Miocene deposits at Jones Wharf, St. Marys County, Maryland. As the clam was much too large to pass through the apical opening of the barnacle, it must have entered when much smaller. It presumably grew inside the barnacle shell until it became too large to open its valves, whereupon it starved to death.

The appearance of this unique combination is shown in figure 1. The barnacles are *Balanus concavus* Brown. The clam (figure 2) was not identified precisely, but it is apparently an immature venerid form. The small hole in its valve is an accidental breach.

The hole in the basis of the barnacle, a fresh break made in removing the specimen from the detritus in which it was embedded, measures 13×20 mm.; the basis of the barnacle, 33×30 mm.; the height, 21 mm. The dimensions of the clam are: anteroposterior axis, 23 mm.; height (umbo to opposite margin), 21 mm.; thickness, 13 mm. It was necessary to detach the additional large area of the basis indicated by the dotted lines in figure 1, A, before the clam could be removed.

As the simplest explanation of how the clam entered the cavity of the barnacle is that it accidentally fell in after the latter had died and its scutum and tergum had fallen off, it becomes of importance to ascertain, if possible, whether the barnacle was growing in such a position that it would retain the clam, once it had entered. Accordingly, the axial positions of 671 specimens of *B. balanoides* growing in heavy seats on two vertical posts were recorded. It was found that 636 of the barnacles (95 percent) grew with their long axes parallel to the long axes of the posts (vertical) and with their carinal plates uppermost; that 38 (3½ percent) grew with their

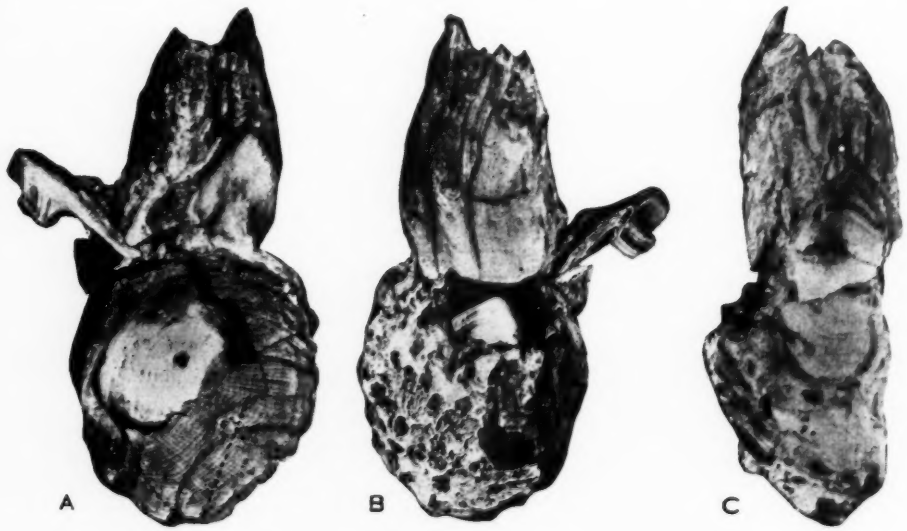

FIG. 1—Miocene clam imprisoned in barnacle shell, ×1. A, view from beneath; B, view from above; C, lateral view.

carinae pointing downward; and that 17 (1½ percent) grew with their long axes approximately transverse to those of the posts. This indicates that barnacles tend to grow with their openings uppermost, and it therefore seems reasonably certain that the specimen

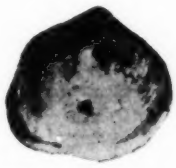

FIG. 2—Clam after removal, ×1

of *B. concavus* was growing in some such position as shown in figure 1, C, with the apical opening pointed upward like a vest pocket. In this position it is easy to understand how it might retain a clam deposited in its interior by water currents.

The maximum width of the apical opening of the barnacle is only 13 mm. The height of the clam could therefore not have exceeded this figure at the time it became imprisoned, and consequently the clam must have increased at least 8 mm. in height while living within the barnacle shell. It is not possible to say how long the clam lived in the barnacle shell, particularly as its growth rate may have been retarded by its cramped quarters, but comparison with the data collected by Newcombe[1] for the growth of *Mya arenaria* suggests that the interval may have amounted to one growing season. It is an interesting commentary on the abundance of food in Miocene seas that an ordinarily motile form like this clam could continue to live and grow for a considerable time in a condition of forced immobility in which it was dependent on water currents for its food.

[1] NEWCOMBE, CURTIS L., *1935*, Growth of *Mya arenaria* in the Bay of Fundy region: *Canadian Jour. Research*, vol. 13, sec. D, pp. 97–137.

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